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Potential Crop Rotation and Insurance Adoption Response to Changes in the Federal Crop Insurance Program

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The 2014 Farm Bill made crop insurance the foundation of a grain farm's revenue safety net. Crop insurance is a public sector/private sector partnership where the public sector provides, on average, 60% subsidy of insurance premiums and 100% subsidy of the administrative and overhead costs (RMA). The public sector's support of crop insurance is instead of ad hoc disaster bills in response to a weather-related disaster. Crop insurance is designed for farmers to be proactive in managing their farm's risk and to provide a more market-based solution to managing disaster recovery.

As policymakers discuss the next Farm Bill, competing ideas will arise over the best policies that help farmers while meeting declining baseline budgets. Critics of crop insurance would like to see the subsidies reduced to reduce the government's obligation and to encourage farmers to pay a more significant percentage of the insurance premium.

Any proposed changes to crop insurance are not currently defined in policy proposals with a discussion of possible changes circulating in agricultural media. One alternative could be a limit on the subsidy dollar value a farm business receives. This policy alternative would adversely affect farms planting more acres to economize on machinery and equipment.

Any changes to the insurance program will increase the farmer's cost of the program. However, managerial response to the crop insurance products used and the coverage level purchased is not well understood. The farmer's attitude to risk will determine which crop insurance tool, if any, is used to manage revenue or yield risk. Risk-neutral farmers would choose the insurance policy that provides the largest expected revenue net of insurance costs. Risk-averse farmers may choose a policy that provides a lower net revenue if there is sufficient downside risk protection provided by the insurance policy. Some farmers may choose to reduce coverage levels or change from a farm-level product to an area product. Depending on the cost of the insurance and the risk protection provided, some farmers may decide it is better to self-insure. If the crop insurance subsidy level is constrained, farmers may choose to self-insure one crop to preserve scarce subsidy dollars for a crop that is more expensive to produce and has more risk.

The objective of this paper is to simulate the risk-efficient crop insurance portfolio for a Western Kentucky corn-soybean farm for varying levels of risk aversion. Portfolios will be simulated for 1500, 2500, and 5000-acre farms assuming no subsidy constraint and a $40,000 subsidy constraint. The portfolio model assumes a corn-soybean rotation and that all acres must be planted. These constraints illustrate how risk-averse farmers may react to subsidy constraints and potential changes in the optimal insurance product given rotation, acreage, and policy constraints.

Data and Methods

A stochastic simulation model of a Western Kentucky corn and soybean farm generates distributions of revenue, indemnities, actuarially fair premiums and insurance subsidies. This simulation model includes farm and county yield risk, projected price and harvest price variability, and U.S. and Kentucky marketing-year average (MYA) price variability. The model is described in detail in Jaromczyk, Davis, and Mark. The following discussion will provide an overview of the simulation model used to generate the distributions to be optimized by the portfolio model.

A multivariate empirical (MVE) distribution defines corn and soybean yields at the farm and county level. The distributions are the percent deviates from trend yields using data from 1996 to 2016. The farm yields are from the Kentucky Farm Business Management program for a farm in Daviess County, Kentucky. County corn and soybean yields for Daviess County Kentucky are from USDA-NASS.

The crop insurance Projected Price (PP) for corn and soybean crop insurance is the December corn and November soybean future contracts closing price in February. The crop insurance projected prices are simulated as part of the MVE distribution with the yield distributions. The crop insurance harvest price (HP) is simulated by a distribution of the ratio of the HP to PP from 1996 to 2016. For each iteration in the simulation model, a random price ratio is drawn and multiplied by the stochastic projected price. The price ratio captures the historical seasonality from February to October. The ratios are included in the MVE distribution with the other prices and yields.

The Kentucky marketing-year average price is used to calculate the stochastic cash revenue assuming the farmer has average marketing skills. The stochastic Kentucky MYA prices are also included in the MVE distribution of yields and crop insurance prices. The stochastic yields and prices are used to generate distributions of crop insurance indemnities, actuarially fair premiums, and crop insurance premium subsidies. The detailed equations of the simulation process are presented in Jaromczyk, Davis, and Mark.

Farmers have the opportunity to purchase insurance that protects revenue or yield at the farm or county level. The revenue protection (RP) insurance at the farm-level is most commonly purchased as revenue is guaranteed based on the farm’s historical yields and the larger of the projected or harvest price. Farmers purchase this insurance using enterprise unit, as the premiums are less expensive than the insurance for basic or optional units. An indemnity is triggered whenever the harvest revenue is less than the revenue guaranteed by RP insurance.

Revenue protection with harvest price exclusion (RP-HPE) is a similar product but only provides revenue protection using the projected price and does not increase the revenue guarantee if price increases at harvest. RP-HPE premiums tend to be less expensive than RP insurance.

Yield protection (YP) insurance only protects against yield loss. An indemnity is paid whenever the harvested yield is below the bushels guaranteed. If there is a production loss, the indemnity is the bushel deficit valued at the projected price. Since only yield risk is protected, YP insurance is the cheapest of the three farm-level insurance simulated in this paper.

The farm-level insurance products provide protection based on the farm's historical production (APH) and the coverage level purchased. Farm-level products have coverage levels at the 50, 55, 60, 65, 70, 75, 80, and 85 percent coverage levels.

The area insurance products function the same as the farm-level products except that the county trend yield is used instead of the farm's APH yield. Because of a potential yield basis between the farm and the county yield, farmers can purchase a productivity factor of up to 1.20 to scale up the coverage. The area insurance products can be purchased at the 70% to 90% coverage levels.

The actuarially fair insurance premiums are stochastic by crop and year and are simulated as functions of the liability insured. The RMA crop insurance premium calculator was used to calculate historical actuarially fair premiums for the insurance products analyzed for Daviess County from 2011 to 2016 crop years for the farm's trend-adjusted corn and soybean APH yields and the area products (RMA). The simulation process is described in detail in Jaromczyk, Davis, and Mark.

The simulated cash revenue, crop insurance indemnities, premiums, and subsidies are simulated 500 iterations per year for a five-year period. For each iteration, the market revenue and net insurance indemnities are calculated by crop and insurance product for each simulated year. The revenue and net indemnities are discounted to a present value amount using a 5% discount rate (Shepherd). The annualized value is then calculated using a 5% discount rate (Shepherd). The stochastic simulation and CE analysis are performed in Simetar, an add-in to Excel (Richardson).

The distributions of the annualized revenues are inputs in a portfolio optimization model that determines the optimal set of corn and soybean insurance products for varying levels of risk aversion. The objective function of the portfolio model is to maximize the return over total variable costs and rent subject to a constraint on the variability of portfolio returns. For the risk neutral portfolio, the variability of returns does not matter, and the portfolio of insurance provides the farm's largest expected return. As risk aversion increases, the portfolio substitutes the higher return but more variable insurance products with products and coverage levels with a lower standard deviation. The optimization model is constrained to maintain a corn-soybean crop rotation. Another constraint forces all acres to be planted.

The optimization model determines risk efficient portfolios simultaneously for corn and soybeans for 1500, 2500 and 5000-acre farms. The base scenario assumes the current crop insurance subsidy policy. The alternative scenario assumes a $40,000 constraint on the total crop insurance subsidy per farm.

The optimization model is optimized by GAMS using the Minos solver. A technique developed by McCarl and Bessler is used to adjust the objective function for risk aversion using the Z-statistic to weight the variability in returns.

Results

The per acre revenues for corn and soybeans for selected crop insurance products and no risk management are included in Table 1. For corn, the ARP-90 provides the largest expected revenue but has the second largest coefficient of variation. The large coefficient of variation suggests that as risk aversion increases, a product with lower relative risk will be preferred. The cash-only revenue is higher than that of purchasing YP at the 85% coverage level. However, YP-85 has a lower relative variability, which may force the allocation within the risk optimization model as risk aversion increases.

For soybeans, ARP at the 90% coverage has the largest average revenue but also the highest coefficient of variation (Table 1). AYP at 90% coverage or the cash-only alternative has lower returns but a similar relative risk (Table 1). The minimum annualized revenue for doing nothing is larger than that for ARP-90 although this is one iteration from 500 iterations.

The average portfolio return over total input costs and cash rent for the 1500, 2500, and 5000-acre farms are reported in Table 2. The change in portfolio return when a $40,000 subsidy limit is applied is included to measure the average impact on farm returns for the policy change for increasing levels of risk-aversion. The base scenario returns show how risk-aversion affects the optimal portfolio as lower average returns are accepted in the portfolio as a trade-off for lower variability in returns.

A $40,000 limit on the amount of crop insurance premium subsidy would not affect portfolio returns for the 1500-acre farm. The constraint is binding for the 2500-acre farm and reduces returns for the risk-neutral farm by almost $13,000. The difference in portfolio returns diminishes as risk aversion increases because both portfolios become more conservative and both allocate to insurance products with lower average returns with lower variability (Table 2).

The subsidy constraint is more pronounced for the 5000-acre farm, as the return for the risk-neutral portfolio is about $50,000 less than the unconstrained portfolio (Table 2). The difference in portfolio returns diminishes as risk aversion increases because the crop insurance products used in the portfolio have lower average returns and smaller standard deviations of returns (Table 2).

Optimal Crop Insurance Portfolio for Corn

The optimal risk-efficient portfolio for the Base scenario for corn is to use ARP at the 90% coverage level for risk-neutral managers. As risk-aversion increases, the optimal portfolio adds RP 85% coverage level to the ARP 90% insurance. The RP-85 has the second smallest coefficient of variation for corn. For the most risk-averse producer, the optimal portfolio is a combination of farm-level and area products. Because of the positive correlation in yields, the ARP 90 product provides the largest expected return for the cost of the insurance. The shift to RP 85% coverage provides better expected net returns as risk aversion increases as the farm-level product is more risk-efficient than the area products. The portfolio adds the farm-level YP insurance at the 85% coverage level at the highest level of risk aversion and reduces the percentage of ARP. The portfolio adds AYP to the portfolio as the premium is cheaper than for ARP insurance (Figure 1).

When the $40,000 subsidy constraint is applied to the 1500-acre farm, there is no change to the optimal portfolio described in Figure 1. The constraint is not binding at the projected price levels simulated. The actuarially fair crop insurance premiums are a function of the liability insured. The simulation model did not consider the effect of subsidy constraints if the grain markets repeated the period of record corn and soybean prices like in the 2011 to 2013 crop years. The

1500-acre farm might have a more binding subsidy constraint if crop insurance prices returned to the 2011 to 2013 levels with the same volatility in the futures market as that period.

The subsidy constraint changes the risk-efficient corn crop insurance portfolio for the 2500-acre corn-soybean farm. The risk-efficient corn crop insurance portfolio for the 2500-acre farm is a combination of ARP and ARP-HPE both at the 90% coverage level for a risk-neutral farmer (Figure 2). The subsidy constraint uses ARP-HPE for 90% of the corn area as the harvest price exclusion option is a lower cost alternative to crop insurance with a slightly lower expected return than ARP-90 insurance. The lower premium with a corresponding lower subsidy allows for more area protected by insurance instead of being self-insured. Again, the positive yield correlation makes this result feasible. If the correlation between the farm and county yields was weaker than the correlation currently simulated, then the area products may not be as prominent in the risk-efficient portfolio as currently simulated (Figure 2).

As risk-aversion increases, the 2500-acre farm corn portfolio uses a combination of ARP at the 90% coverage level and self-insurance. For more risk-averse farmers, the use of farm-level products like RP 85% coverage and YP 85% coverage enters the portfolio because of the smaller coefficient of variation as compared to self-insurance. Self-insurance is not in the risk-efficient portfolio for the most risk-averse corn farmer as the portfolio is a combination farm-level and area products protecting 55% and 45% of corn acres, respectively (Figure 2).

The risk-efficient portfolio of corn insurance products for the 5000-acre corn-soybean farm is shown in Figure 3. For a risk-neutral farmer, the portfolio with the highest return over total variable costs and rent is a combination of self-insurance and ARP-HPE at the 90% coverage level. The $40,000 subsidy constraint is binding, and the area insurance product provides the largest expected return. As risk-aversion is increased, the portfolio increases the percentage of corn acres that are self-insured. For more risk-averse farmers, the portfolio is about 40% of the corn area self-insured and the remaining acres protected by AYP 90% coverage and ARP 85% coverage. More acres are allocated to AYP 90% than to ARP 85% coverage because the yield only insurance product has a lower premium and lower subsidy than the revenue products (Figure 3).

The portfolio models for corn farmers imply that once the subsidy constraint is reached, risk-averse farmers will use the area protection to supplement the protection provided by farm-level insurance products if the yields are correlated. Eventually, the subsidy constraint is sufficiently binding that self-insurance is the risk-efficient alternative as it is impossible to simultaneously buy crop insurance, maintain the rotation, and plant all of the acres.

Sensitivity analysis on removing the rotation constraint (not shown) is the removal of corn from the crop-mix. Corn is more expensive to produce and has greater yield risk than soybeans. The insurance premiums are higher for corn than for soybeans, which makes soybeans more risk-efficient in the portfolio model. If the constraint forcing all acres planted is removed, then extremely risk-averse farmers would not plant 100% of the planned area and what is planted is planted to soybeans.

<u>Optimal Crop Insurance Portfolio for Soybeans</u>

The optimal portfolio of crop insurance products for soybeans for the 1500, 2500, and 5000-acre farms for the base scenario is shown in Figure 4. This portfolio for the risk-neutral farmer is 100% ARP at the 90% coverage level. The positive correlation in between farm and county yields and that area crop insurance products are less expensive makes this alternative feasible for farmers that are not concerned about the variability in returns (Figure 4). As risk aversion increases, the optimal portfolio is to self-insure and use AYP at the 90% coverage. While the area revenue product has the larger expected return, the area yield product is cheaper and provides the best return for the variability. The use of self-insurance on about 20% of soybean acres regardless of the level of risk-aversion reinforces the anecdotal evidence of Western Kentucky farmer's preference to not purchase insurance as soybean crop insurance "doesn't pay." Imposing a $40,000 subsidy limit constraint on the 1500-acre corn-soybean does not change the risk-efficient portfolio, as the subsidy constraint is not binding.

The risk-efficient soybean portfolio for the 2500-acre farm illustrates how managers would prefer to self-insure their soybeans and use the scarce subsidy dollars for the higher cost and more risky corn crop (Figure 5). As risk-aversion is increased, the optimal mix of insurance is the AYP at the 90% coverage with self-insurance. The area yield product is less expensive than the revenue products. The AYP insurance would reduce variability in returns while preserving subsidy dollars for corn. The preference to self-insure soybeans remains for the most risk-averse farmers with about 40% of the soybean acres not protected by insurance (Figure 5).

The 5000-acre farm would increase the amount of self-insurance for soybeans to preserve scarce subsidy resources for corn. The optimal crop insurance mix for soybeans would be to self-insure 100% for a risk-neutral farmer and to add AYP at the 90% coverage level to the portfolio as risk-aversion increases (Figure 6). The optimal portfolio for the most risk-averse soybean farmer would be about 65% self-insured with the remaining 35% insured with AYP at the 90% coverage level (Figure 6).

The soybean portfolio implies that if farmers try to maintain the crop rotation, the soybean enterprise will subsidize the corn enterprise's use of crop insurance. The corn acres will use area products that are not as effective as the farm-level products if there is significant yield basis risk between the farm and county yields.

This portfolio model allows blending of farm-level and area products, which masks the impact of the subsidy constraint on optimal insurance product purchased. Forcing either area or farm-level insurance product purchasing decision into the model would likely result in an allocation to lower coverage-levels for the farm-level products before switching to the area product. If the correlations in yield end up being weaker than those simulated in this study, additional switching will take place.

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Table 1. Simulated Corn and Soybean Revenue ($/Acre) with Insurance Indemnities Net of Premiums Paid for Selected Insurance Products Simulated.

Corn Revenue ($/Acre) Including Net Insurance Indemnities				
	Mean	**Std Dev**	**Min**	**Max**
Cash Only	$659	$40	$532	$749
YP 85	$649	$28	$580	$720
RP 85	$666	$30	$588	$751
AYP 90	$669	$38	$553	$794
ARP 85	$674	$49	$541	$811
ARP 90	$690	$57	$551	$837
ARP-HPE 90	$684	$58	$529	$853
Soybean Revenue ($/Acre) Including Net Insurance Indemnities				
	Mean	**Std Dev**	**Min**	**Max**
Cash Only	$554	$25	$482	$613
ARP 90	$563	$41	$481	$730
AYP 90	$562	$26	$490	$639

Table 2. Mean Portfolio Return for Base Scenario and Change in Returns with Subsidy Limit for a 1500, 2500, and 5000-Acre Farms for Various Levels of Risk Aversion[1/].

Mean Portfolio Return over Total Variable Costs and Rent for Base Scenario and Dollar Change from Base by Risk Aversion Level.						
	1500 Acre Farm		**2500 Acre Farm**		**5000 Acre Farm**	
Risk Level	**Base**	**Susidy Limit**	**Base**	**Susidy Limit**	**Base**	**Susidy Limit**
50	$45,496	+$0	$75,826	-$12,958	$151,652	-$49,569
55	$42,302	+$0	$70,503	-$9,513	$140,996	-$40,181
60	$36,532	+$0	$60,880	-$1,807	$121,761	-$23,958
65	$33,810	+$0	$56,351	-$1,933	$112,693	-$20,827
70	$32,481	+$0	$54,138	-$3,421	$108,275	-$19,236
75	$31,202	+$0	$52,003	-$3,583	$104,011	-$16,694
80	$30,322	+$0	$50,537	-$3,694	$101,074	-$14,939
85	$29,654	+$0	$49,422	-$3,779	$98,843	-$14,681
90	$29,101	+$0	$48,502	-$4,532	$97,004	-$13,926
95	$27,964	+$0	$46,607	-$4,340	$93,213	-$10,332

[1/] The base scenario is the portfolio for the current subsidy schedule. The subsidy limit is the change in the portfolio's value when the subsidy is constrained to $40,000 per farm.

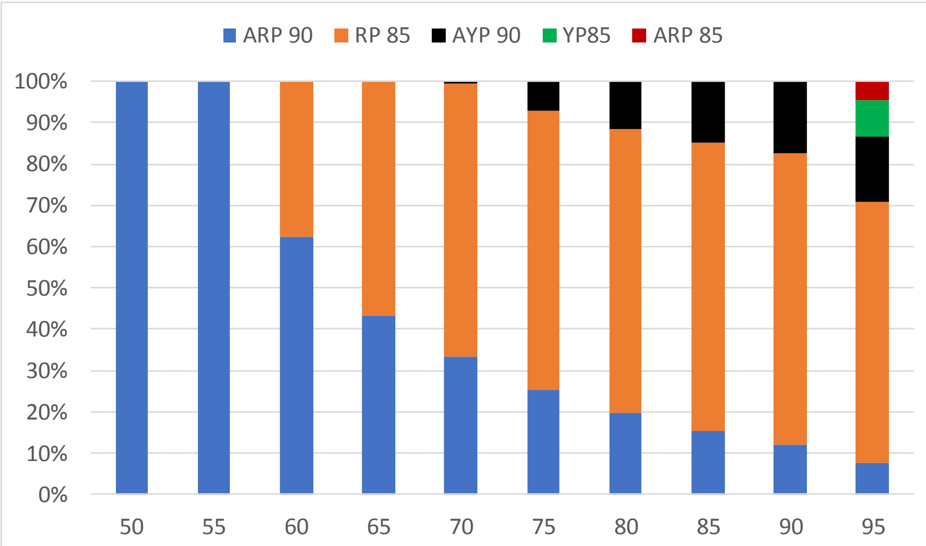

Figure 1. Risk Efficient Crop Insurance Portfolio for Corn for the Base Scenario for the 1500, 2500, and 5000-Acre Corn-Soybean Fars.

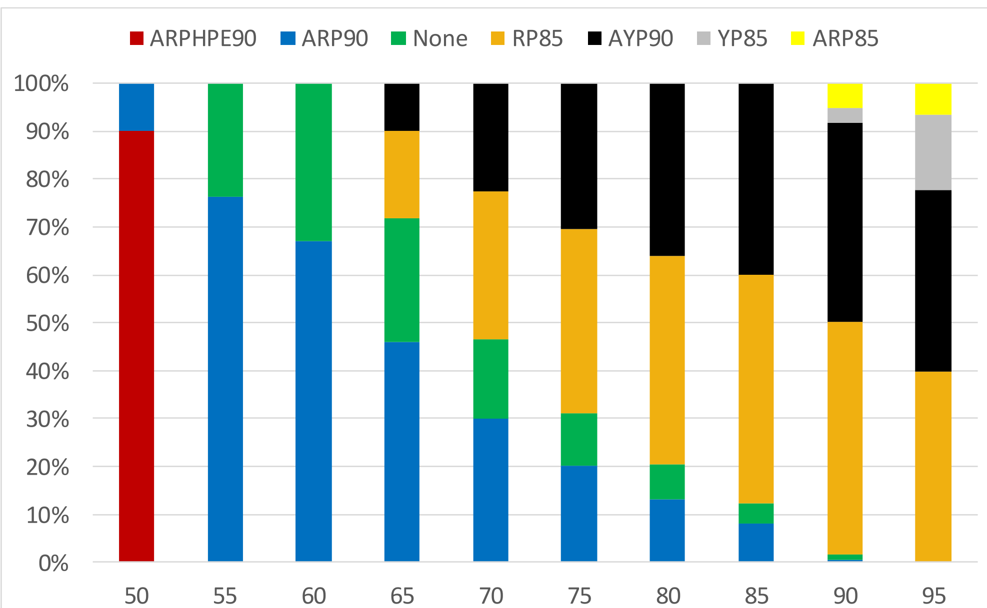

Figure 2. Risk Efficient Crop Insurance Portfolio for Corn for the 2500-Acre Corn-Soybean Farm with a $40,000 Crop Insurance Subsidy Constraint.

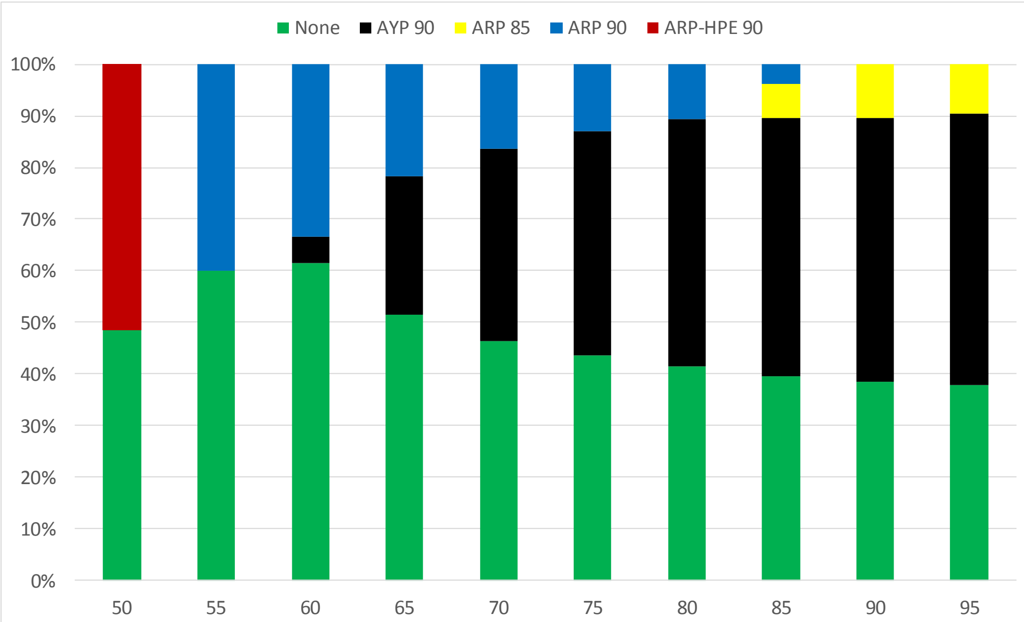

Figure 3. Risk Efficient Crop Insurance Portfolio for Corn for the 5000-Acre Corn-Soybean Farm with a $40,000 Crop Insurance Subsidy Constraint.

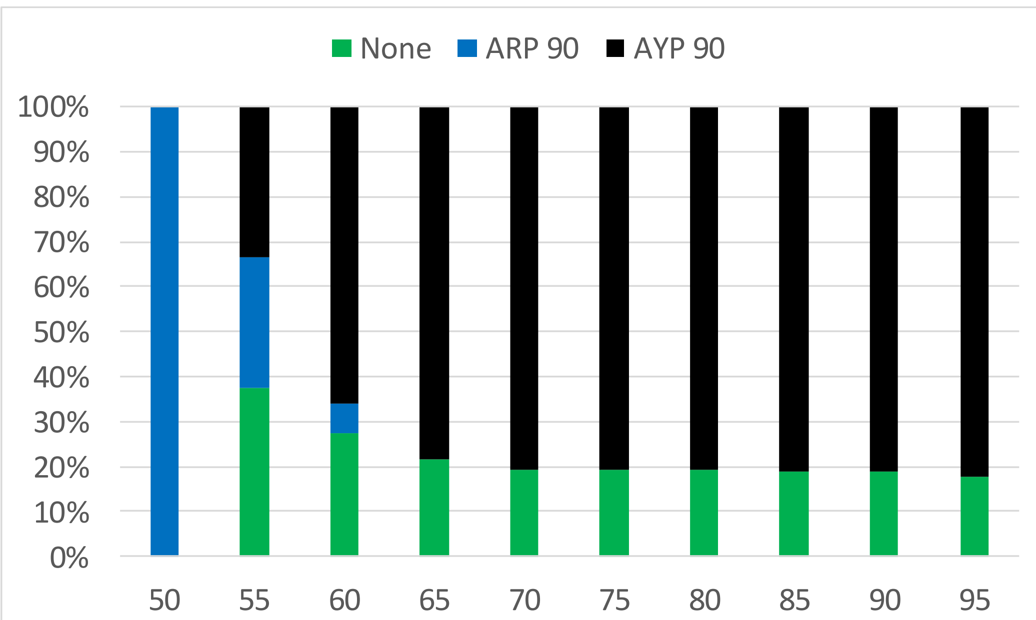

Figure 4. Risk Efficient Crop Insurance Portfolio for Soybeans for the Base Scenario for 1500, 2500, and 5000-Acre Corn-Soybean Farms.

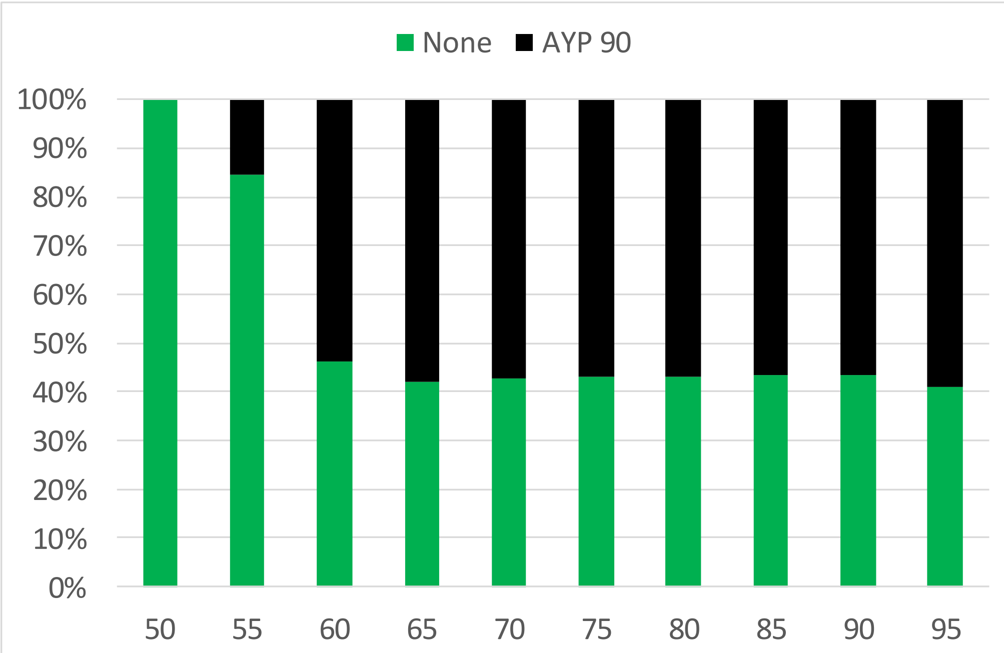

Figure 5. Risk Efficient Crop Insurance Portfolio for Soybeans for the 2500-Acre Corn-Soybean Farm with a $40,000 Crop Insurance Subsidy Constraint.

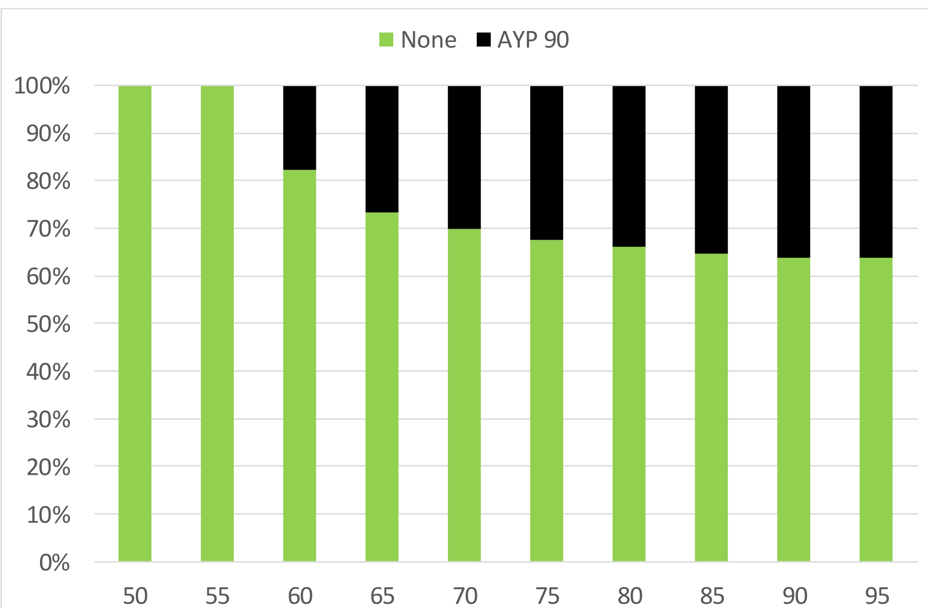

Figure 6. Risk Efficient Crop Insurance Portfolio for Soybeans for the 5000-Acre Corn-Soybean Farm with a $40,000 Crop Insurance Subsidy Constraint.