Risk and Return to IP Grain Production: The Case of High Oil Corn [*]

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ABSTRACT

Returns for soybeans, commodity corn and high oil corn under an export and domestic market buyer's-call contract were simulated. High oil corn is competitive with commodity corn when yield drag is two percent and bundling reduces seed cost. Commodity loan rate is important in reducing high oil corn price risk.

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Problem Statement

Farm managers are continuously evaluating strategies to improve farm profitability. One strategy may involve production of specialty grains, as specialty grains offer a premium over commodity grains. For example, high oil corn (HOC) offers a premium of $0.25/bu. over commodity corn if the grain contains 8% oil (Optimum Quality Grains, L.L.C. (1999a)).

However, there are risks associated with HOC production. One risk is that HOC may yield less than commodity corn and have greater yield variability (Thomison et al.; Thomison and Geyer (1998); and Thomison and Geyer (1999)). Another source of production risk is the variability in the value-added trait. For instance, the oil content in high oil corn averages 7.2%, but can range from 6.5% to 8% (Kaplan 2000). Since the premium depends upon the amount of oil in the grain, the variability in oil content introduces uncertainty about the ability of HOC premiums to cover any additional production costs.

In addition to production risks, HOC production may involve increased price risk. The export market buyer's call contract offered by Optimum Quality Grain uses the basis from the export market. As a result, the price producers' receive may be greater or less than the price for commodity corn. While grain producers are familiar with the basis risk associated with the futures market, they are likely less knowledgeable of export basis variability.

Many high oil corn production contracts are based on a buyer's call, where the producer is responsible for drying, storing and maintaining grain quality until the buyer requests delivery. The delivery date is not known with certainty; thus, the grain could be delivered during a period of low commodity prices. Delivery date uncertainty, called 'buyer's call risk' in this paper, has the potential to increase price risk, reduce cash flows, and cause increased debt.

Producers have to decide the type of contract to enter into to produce HOC. Producers have the choice of either an export market buyer's call contract or a domestic market buyer's call contract. The export contract price is based off of an export market and offers larger premiums than the domestic contract. However, the export contract has additional price risk. Producers need to know if an increased premium is worth an increase in price risk, production risk, and buyer's call risk.

The objective of this paper is to evaluate the risks and returns for producing high oil corn compared to producing commodity corn in Indiana. The return to unpaid labor, land and machinery for both an export and domestic buyer's call contract will be calculated using a stochastic simulation model. The simulation model will include the effects of production risk, price risk, and buyer's call risk. The second objective is to compare HOC, commodity corn, and soybean distributions for different levels of risk aversion. Even if HOC has a larger mean return than commodity corn, risk averse producers may not choose to produce HOC because of increased variability in returns. Stochastic dominance is a way to consider risk aversion when comparing distributions. A third objective is to determine the potential for HOC to enter a corn-soybean crop mix for different levels of risk aversion. Results of this study are of interest to producers, professional farm managers, and extension economists.

The next section of this paper provides a review of literature concerning high oil corn production. The data used to develop and a description of the deterministic and stochastic simulation models are then presented. The results from the simulation model, stochastic dominance analysis, and the potential for diversification are then discussed. The last section provides the primary conclusions and suggestions for future research.

Literature

HOC may be a profitable crop because the Top Cross Technology® developed by DuPont has been able to increase corn oil content by 3.4%-3.7% over commodity corn while only reducing yields by 5-10%. High oil corn yields may be lower than commodity corn because the seed is a blend, where 8-10% of the plants in an acre shed pollen and 90%-92% of the plants in an acre produce grain (Lauer). While the average yield drag was 13.7% in 1996, results from university test plots indicate the yield drag has been reduced to 2-4% in 1999 (Thomison et al.; and Thomison and Geyer (1999)). Because of the yield drag and to ensure enough pollen is shed, agronomists suggest that the planting rate for high oil corn be increased by 2,000 plants per acre over commodity corn (Lauer). Besides having lower yields, test plot data also indicate that HOC yields vary 14% more than commodity corn (Thomison et al.; Thomison and Geyer (1998); and Thomison and Geyer (1999)).

High oil corn is often produced under production contracts that are based either on an export market price or a local market price. Producers contract the number of acres of HOC they intend to produce instead of contracting a specific bushel quantity. Both contracts require the producer to purchase the high oil seed from a list of approved seed companies, and producers are charged a per bag technology fee. However, some contracts offer a discount on the technology fee if the producer purchases at least 50% of their total corn herbicide needs from DuPont (Optimum Quality Grain, L.L.C. (1999a)).

The price producers' receive for a domestic market buyer's call contract is the cash corn price less any discounts plus the oil premium. The premium is $0.00 per bushel for 6.0% oil and increases $0.01 per bushel for every 0.1% increase in oil for oil contents between 6.1% and 7.0%. For oil contents between 7.1% and 8.0%, the premium increases by $0.005 per bushel for every 0.1% increase in oil. The maximum premium is $0.15 per bushel for oil concentration levels of 8% or more (Optimum Quality Grain, L.L.C. (1999b)).

The price producers' receive for an export buyer's call contract is the corn price basis the export market less discounts plus the oil premium. The premium scale is $0.05 per bushel at 6.0% oil and increases $0.01 per bushel for each 0.1% increase in oil content. The maximum premium is $0.25 per bushel at oil levels of 8.0% or above. The first 140 bushels produced per acre receives the full premium with any additional bushels receiving one-half of the stated per bushel premium (Optimum Quality Grain, L.L.C (1999a)).

Data and Methods

Data used to simulate high oil corn yield and oil content are from Ohio State University test plots conducted from 1995-1999 (Thomison et al.; Thomison and Geyer (1998); and Thomison and Geyer (1999)). Data were available for both the commodity grain parent and the high oil corn varieties. Since the test plots included hybrids that were experimental, only hybrids commercially available with yields above the test plot average for each year were included in this study. The average high oil corn yield was 129.5 bushels/acre while the average yield for the grain parent was 142.8 bushels/acre (Table 1). The average oil content was 7.2% and ranged from 6.2% to 8.6% over the five-year period.

Commodity corn and soybean yields and prices were simulated from data available through Indiana Agricultural Statistics Service for the 1972-1998 crop years. The average corn and soybean yields were 113.5 bu./acre and 36.9 bu./acre, respectively (Table 1). The corn and soybean prices are the marketing-year average (MYA) price for Indiana for the 1972-1998 marketing years. Data from 1999 were not included because the marketing-years for corn and soybeans do not end until August 31, 2000. The average MYA corn and soybean price were \$2.49/bu. and \$6.22/bu., respectively.

Gulf price data for the 1972-1998 marketing years were used to simulate the export price variability (USDA ERS). The price producer's receive for HOC under the export contract is the gulf price less transportation cost. The freight rail rate for the Norfolk Southern rail road (Baldwin) is used as an estimate of the cost of transporting grain from Central Indiana to the Louisiana gulf.

Deterministic Model

Crop enterprise budgets are developed for commodity corn, soybeans, and for high oil corn produced under both an export market and a domestic market buyer's call contract. The production costs are based on a corn-soybean rotation for average yielding soils in Indiana (Doster, et al.). Seed prices for No. 2 corn and high oil corn are from Pfister hybrid, with high oil seed corn charged a \$30/bag technology fee (Brown). The per acre seed cost for HOC also reflects an increased planting rate of 2,000 plants per acre. The fertilizer rates are based upon the Tri-State Fertilizer recommendations (Vitosh, Johnson, and Mengel).

The deterministic model calculates the per acre return to unpaid labor, land and machinery for high oil corn, commodity corn and soybeans. The deterministic models for commodity corn, soybeans, high oil corn produced under a domestic contract, and high oil corn produced under an export contract are described in equations 1, 2, 3, and 4, respectively.

$$\pi_{\#2} = \overline{P}_{\#2}\overline{Y}_{\#2} - \overline{C}_{\#2} \qquad (1)$$

$$\pi_{SB} = \overline{P}_{SB}\overline{Y}_{SB} - \overline{C}_{SB} \qquad (2)$$

$$\pi_{HOC}^{D} = \overline{P}_{HOC}^{D}\overline{Y}_{HOC} + \gamma_{HOC}^{D}\overline{O}_{HOC}\overline{Y}_{HOC} - \overline{C}_{HOC} \qquad (3)$$

$$\overline{\pi}^{E}_{HOC} = \overline{P}^{E}_{HOC}\overline{Y}_{HOC} + \gamma^{E}_{HOC}\overline{O}_{HOC}\overline{Y}_{HOC} - \overline{C}_{HOC} \tag{4}$$

$$\overline{P}^{E}_{HOC} = \overline{P}^{Gulf}_{\#2} - r_{\#2} \tag{5}$$

where $\overline{Y}_{\#2,}, \overline{Y}_{SB}$, and $\overline{Y}_{HOC}$ are the per acre average yield for No. 2 corn, soybeans and HOC. $\overline{P}_{\#2}$ is the average sales price for commodity corn, $\overline{P}_{SB}$ is the average sales price for soybeans, $\overline{P}^{D}_{HOC}$ is the average sales price for high oil corn produced under a domestic buyer's call contract, and $\overline{P}^{E}_{HOC}$ is the average price for high oil corn produced under an export market buyer's call contract. The export price, $\overline{P}^{E}_{HOC}$, is the Gulf price for commodity corn, $\overline{P}^{Gulf}_{\#2}$, less transportation costs, $r_{\#2}$, as shown in equation 5. The parameters γ^{D}_{HOC} and γ^{E}_{HOC} denote the per bushel oil premiums for the domestic and export contracts based on the level of oil content in HOC, $\overline{O}_{HOC}$. The variable $\overline{C}_{i}$ is the per acre production costs (e.g. seed, chemicals, fertilizer, fuel, repairs, hauling, interest, and insurance/miscellaneous) for No 2 corn, soybeans, or high oil corn.

As described in equations 3, 4, and 5, HOC yield, oil content, and per acre production costs are the same under both the domestic and export market buyer's call contract. The contracts differ in the price received and the oil premium schedules.

Stochastic Simulations

While the deterministic model provides some insight into the economics of HOC production, production risks, price risks, and basis risks are not considered. To address these issues, a stochastic simulation model is developed to determine the effects of these risks on the per acre return to unpaid labor, land, and machinery. This section describes the stochastic processes used in the simulation model.

The stochastic return to unpaid labor, land and machinery is again calculated for commodity corn (equation 6), soybeans (equation7), HOC produced under a domestic buyer's call contract (equation 8), and for HOC produced under an export market buyer's call contract (equation 9).

$$\tilde{\pi}_{\#2} = \tilde{P}_{\#2}\tilde{Y}_{\#2} - \tilde{C}_{\#2}^{FERT} - \tilde{C}_{\#2}^{DRY} - \overline{C}_{\#2} \quad (6)$$

$$\tilde{\pi}_{SB} = \tilde{P}_{SB}\tilde{Y}_{SB} - \tilde{C}_{SB}^{FERT} - \overline{C}_{SB} \quad (7)$$

$$\tilde{\pi}_{HOC}^{D} = \tilde{P}_{HOC}^{D}\tilde{Y}_{HOC} + \gamma_{HOC}^{D}\tilde{O}_{HOC}\tilde{Y}_{HOC} - \tilde{C}_{HOC}^{FERT} - \tilde{C}_{HOC}^{DRY} - \overline{C}_{HOC} \quad (8)$$

$$\tilde{\pi}_{HOC}^{E} = \tilde{P}_{HOC}^{E}\tilde{Y}_{HOC} + \gamma_{HOC}^{E}\tilde{O}_{HOC}\tilde{Y}_{HOC} - \tilde{C}_{HOC}^{FERT} - \tilde{C}_{HOC}^{DRY} - \overline{C}_{HOC} \quad (9)$$

Yield, price, oil content, fertilizer expense, and drying expense are the stochastic variables in equations 6-9.

The stochastic yields and prices for commodity corn are drawn from a multivariate empirical distribution based on the procedures outlined in Richardson, Klose, and Gray (2000). Equation (10) describes the stochastic yield for commodity corn:

$$\tilde{Y}_{\#2} = \overline{Y}_{\#2}(1 + \tilde{\varepsilon}_{y_{\#2_i}}) \qquad \tilde{\varepsilon}_{y_{\#2_i}} \sim \text{multivariate empirical} \quad (10)$$

where $\tilde{Y}_{\#2}$ is the stochastic yield for No. 2 corn, the deterministic component, $\overline{Y}_{\#2}$, is the average corn yield from 1972-1998, and the stochastic component, $\tilde{\varepsilon}_{y_{\#2_i}}$, is calculated as the percent deviation from the trend corn yield.

Similarly, the stochastic soybean yield component is drawn from a multivariate empirical distribution. The percent errors, $\tilde{\varepsilon}_{y_{SB_i}}$, are calculated as percent deviations from the state soybean trend yield. The deterministic component, $\overline{Y}_{SB}$, is the average soybean yield from 1972-1998. Equation 11 describes the stochastic soybean yield:

$$\tilde{Y}_{SB} = \bar{Y}_{SB}(1+\tilde{\varepsilon}_{y_{SB_i}}) \qquad \tilde{\varepsilon}_{y_{SB_i}} \sim \text{multivariate empirical} \qquad (11)$$

The stochastic yield for HOC is determined through equation (12):

$$\tilde{Y}_{HOC} = \bar{Y}_{\#2}(1-\delta_{HOC})(1+\tilde{\varepsilon}_{y_{HOC_i}}) \qquad \tilde{\varepsilon}_{y_{HOC_i}} \sim \text{multivariate empirical} \qquad (12)$$

The deterministic component for HOC is the same as for No. 2 corn ($\bar{Y}_{\#2}$). The deterministic component is adjusted by the HOC yield drag, δ_{HOC}, and is based on the average yield drag from The Ohio State University test plot data.

Because agronomic conditions are different between Ohio and Indiana, an expansion factor, *X*, is used to impose the properties of the test plot data on the data from Indiana Agricultural Statistics. The error term drawn for No. 2 corn ($\tilde{\varepsilon}_{y_{\#2}}$) is multiplied by the expansion factor, X, to derive the error term for HOC ($\tilde{\varepsilon}_{y_{HOC_i}}$):

$$\tilde{\varepsilon}_{y_{HOC_i}} = \tilde{\varepsilon}_{y_{\#2_i}} X \qquad (13)$$

The expansion factor (X) is the coefficient of variation of Ohio test plot HOC yields divided by the coefficient of variation for Ohio test plot No. 2 corn yields:

$$X = \frac{\sigma_{\tilde{\varepsilon}^{Ohio}_{HOC_i}}}{\sigma_{\tilde{\varepsilon}^{Ohio}_{\#2_i}}} \qquad (14)$$

where the percent errors ($\tilde{\varepsilon}$) are calculated as deviations from the mean test plot yield for high oil corn and commodity corn, respectively. The expansion factor used in this study was 1.139.

The variability in oil content causes the premiums associated with HOC to vary; thus, it is critical that the model describes the variability in oil content. Data analysis revealed no significant correlation between oil content and yield. Thus, oil content is an independent variable simulated as a univariate empirical distribution:

$$\tilde{O}_{HOC} = \overline{O}_{HOC}(1+\tilde{\varepsilon}_{oil_i}) \qquad \tilde{\varepsilon}_{oil_i} \sim \text{univariate empirical} \qquad (15)$$

where the deterministic component, $\overline{O}$, is the average oil content from the Ohio test plots. The percent error terms, $\tilde{\varepsilon}_{oil_i}$, are percent deviations from the average oil content.

The stochastic components of the marketing year average price for No. 2 corn is drawn from a multivariate empirical distribution (Richardson, Klose, and Gray, 2000):

$$\tilde{P}_{\#2} = \overline{P}_{\#2}(1+\tilde{\varepsilon}_{P_{\#2_i}}) \qquad \tilde{\varepsilon}_{P_{\#2_i}} \sim \text{multivariate empirical} \qquad (16)$$

The deterministic component, $\overline{P}_{\#2}$, is the mean marketing-year average price from 1972-1998. The percent errors for the MYA price, $\tilde{\varepsilon}_{P_{\#2_i}}$, are calculated as percent deviations from the average MYA price for the twenty-seven year period.

The correlation between yield and price is appropriately accounted for in the stochastic model. The correlation coefficients and p-values of the variables in the multivariate empirical distributions are included in Table 2. Only the correlation between the Gulf No. 2 corn price and soybean yield is not statistically significant at the 10% level.

The simulation model must also capture the price uncertainty associated with the buyer's call contract. Figure 1 describes the non-parametric approach used to determine the cash prices for both the domestic and export buyer's call contracts. The stochastic No. 2 corn price, $\tilde{P}_{\#2}$, is used as the starting point for the domestic buyer's call price. However, to capture the timing effects of the buyer's call, the price must reflect the month in which the buyer chooses to take delivery of the grain. Discussions with buyers indicate that delivery is usually taken between December and May with equal probability. A uniform distribution with support [1,6] is used with 1 representing December and 6 representing May to determine the delivery month for any given iteration. In addition to determining the month for delivery, the model must also determine the cash price during the given month. To derive a monthly price, a uniform distribution with support [1,27] is used to draw an Indiana monthly price index series and a Gulf monthly price index series from one of the last 27 years. The price index is an index of each month's average cash price divided by the marketing year average price. The uniform draw for the price index series is combined with the uniform draw for the particular month to determine the local price index and Gulf price index, i_{u_1,u_2} and j_{u_1,u_2}, respectively. The product of $\tilde{P}_{\#2}$ and i_{u_1,u_2} is the cash price for the domestic buyer's call contract in the given iteration ($\tilde{P}^{D}_{HOC}$ in the center of Figure 1). The example in Figure 1 shows the results for an iteration where the buyer's call is exercised in March and the cash price is reflective of the price index for March of 1974. Similarly, the price for an export contract is the MYA Gulf price for commodity corn, $\tilde{P}^{Gulf}_{\#2}$, adjusted by the Gulf MYA price index, j_{u_1,u_2}. The same index year used for the local price index is used to determine the Gulf price index. For the example in Figure 1, the Gulf price index corresponding to the 1974 marketing year is used to adjust the Gulf price for March 1974. As a result, the price for high oil corn can be more or less than the No. 2 corn price. Also, the price for HOC under an export contract may be more or less than the price for HOC under a domestic contract.

It is assumed that the buyer's call is exercised in the same month for both the domestic and export contract for any iteration. It should be noted that soybean, No. 2, and HOC prices were not allowed to fall below the state weighted-average loan rates of $5.39/bu for soybeans and $1.91/bu for corn, respectively (Indiana Agricultural Statistics Service, and USDA Farm Service Agency). The loan rates are the county loan rates weighted by each county's share of the state's total soybean and corn production for 1999, respectively.

Finally, the model includes production expenses for soybeans, No. 2, and HOC production. The variable $\overline{C}_i$ denotes the per acre production costs that do not vary with yield (seed, chemicals, fuel, repairs, hauling, interest, insurance/miscellaneous) for soybeans, commodity corn, and HOC (Doster, et al). However, corn fertilizer expense is stochastic as described by equation 17 while equation 18 describes the stochastic per acre fertilizer cost for soybeans (Vitosh, Johnson, and Mengel):

$$\tilde{C}_i^{FERT} = w_N(-27 + 1.36 * \tilde{Y}_i) + w_P(0.37 * \tilde{Y}_i) + w_K(0.27 * \tilde{Y}_i) \qquad (17)$$

$$\tilde{C}_i^{FERT} = w_P(0.80 * \tilde{Y}_i) + w_K(1.40 * \tilde{Y}_i) \qquad (18)$$

The input prices for nitrogen, phosphorous and potassium fertilizer are represented by w_N, w_P, and $w_{K,}$ respectively (Doster, et al.). The per acre cost of drying corn is expressed as equation 19 where the per bushel drying cost is w_{dry} and is the same for high oil and commodity corn:

$$\tilde{C}_i^{DRY} = w_{dry}\tilde{Y}_i \qquad (19)$$

The per unit cost of fertilizer is \$0.13/lb., \$0.20/lb., and \$0.12/lb. for nitrogen, phosphorous, and potassium, respectively. The corn drying cost is \$0.071/bu for both commodity and high oil corn (Doster, et al.).

<u>Stochastic Dominance</u>

The distributions of returns to unpaid labor, land, and machinery for soybeans, commodity corn, and HOC are compared using a stochastic dominance program developed by Cochran and Raskin. First-degree stochastic dominance (FSD), second-degree stochastic dominance (SSD), and stochastic dominance with respect to a function (SDWRF) are used for the pair-wise comparisons of each distribution of return to unpaid labor, land and machinery. Since FSD can not compare distributions that cross, SSD and SDWRF will be used to provide insight of how risk aversion affects the ranking of distributions. SDWRF compares the distributions over different intervals of risk aversion.

Potential for Crop Diversification

The potential for adding HOC to a corn-soybean rotation is analyzed by maximizing the certainty equivalent (CE) of the per acre return to unpaid labor, land and machinery for different levels of relative risk aversion. The CE maximization model is described in equations 20 - 23.

$$\text{Max } CE = \sum_{i=1}^{N} x_i \mu_i - \left(\frac{\rho}{2}\right) \sum_{i=1}^{N} \sum_{j=1}^{N} x_i x_j \sigma_{ij} \qquad (20)$$

subject to:

$$\sum_{i=1}^{N} x_i = 1 \qquad (21)$$

$$x_{SB} <= 0.50 \qquad (22)$$

$$x_i >= 0 \;\; \forall \text{ i} = 1..\text{N} \qquad (23)$$

where ρ is the coefficient of relative risk aversion, μ_i is the average per acre return to unpaid labor, land and machinery for crop *i*, and σ_{ij} is the covariance of returns between crop i and crop j. The parameters μ_i and σ_{ij} are estimated from the simulated distributions. The first part of the right-hand side of equation 20 is the expected return for the crop mix and the second part is the Pratt approximation of the risk premium. The CE maximizing crop mix for different levels of relative risk aversion can be mapped by iteratively solving the maximization problem for several coefficients of relative risk aversion ranging from 0 to 5. The coefficient of relative risk aversion is converted into an absolute risk aversion coefficient before solving the model.

The decision variable is the percentage of an acre allocated to each crop, x_i. Equation 22 is a constraint that forces a rotation of soybeans and either HOC or commodity corn into the CE maximizing crop mix. If equation 22 is removed from the model, only soybeans will be planted.

Equation 21 is a constraint that forces all of the land to be planted while equation 23 ensures that a positive percentage is allocated to each crop.

Description of Scenarios Simulated

The scenarios analyzed in this study are described in Table 3. The base scenario assumes that corn and soybean yields are at the average levels from the last 27 years, and the HOC yield drag equals the test-plot average from 1995-1999. Corn and soybean prices are from USDA baseline projections for 2000. The base scenario also assumes that the producer is not participating in the technology fee rebate program.

Scenario 1 recognizes that the HOC yield drag has been reduced to 2% in 1999 due to improved genetics. Scenario 2 assumes the HOC yield drag is 2% and seed costs are reduced due to the technology fee rebate program. Scenario 3 has the same assumptions as scenario 2 and also assumes that corn and soybean yields are 20% higher. Scenario 4 has the same assumptions as scenario 2 but assumes that corn and soybean prices are at the average level for the last 27 years. Scenario 5 assumes the 2% yield drag, seed bundling, increased yields, and increased prices.

Preliminary Results

The return to unpaid labor, land and machinery for each scenario from the deterministic model are presented in Table 4. The return to commodity corn production is greater than HOC for the base and scenario 1. However, the results from the deterministic model suggest that HOC is competitive with commodity corn when yield drag is 2% and bundling is used to reduce seed costs (Scenario 2). When yields are increased by 20% (Scenario 3), the returns to HOC under the export and domestic contract are greater than the return for commodity corn. When price is increased independently of yield (Scenario 4), the return to HOC under the domestic contract is greater than commodity corn while the return to HOC under an export contract is less than commodity corn. The same result occurs when both prices and yields are increased (Scenario 5).

Summary statistics of the return to unpaid labor, land and machinery for the stochastic model are described in Table 5. The return to commodity corn is greater than the return to HOC at the mean and 75th percentile for the base scenario. When the yield drag is reduced to 2% (Scenario 1), the average return to commodity corn is greater than HOC. However, the return to HOC is greater at the 75th percentile. When bundling is considered (Scenario 2), the return to HOC is greater than commodity corn at the mean and 75th percentile. The results are similar for Scenario 3, as increasing yields will shift the distributions to the right and not change the shape of the distributions. Scenario 4 reveals that HOC is sensitive to price risk as the average return to HOC under the domestic contract is greater than the return to commodity corn. However, the return to HOC under the export contract is $21/acre less than the return to commodity corn. When both prices and yields are increased (Scenario 5), the return to HOC under a domestic contract is greater than commodity corn, and the return to commodity corn is greater than the HOC export contract.

First-degree (FSD), Second-degree (SSD) and stochastic dominance with respect to a function (SDWRF) are used to compare the distributions of returns. For all scenarios, the soybean distributions SSD both the commodity corn and HOC distributions (Table 6). Corn FSD the HOC export contract for the base scenario, and SSD for scenario 1, scenario 4, and scenario 5. When SDWRF is used to compare commodity corn and the HOC export contract distributions, commodity corn dominates for scenario 2 and scenario 3. The only time HOC export SDWRF the commodity corn distribution is for coefficients of relative risk aversion between 0 and 1 for scenario 3. Similarly, commodity corn SSD the HOC domestic contract distribution for the base scenario, scenario 1, and scenario 4. Corn SDWRF the HOC domestic contract distribution for scenario 2, scenario 3, and Scenario 5. The only time the HOC domestic contract SDWRF the commodity corn distribution is for coefficients of relative risk aversion between 0 and 1 for scenario 3. HOC domestic FSD HOC export for scenario 4 and scenario 5. HOC domestic SDWRF the HOC export contract distribution for the base scenario, scenario 1, scenario 2, and scenario 3. The HOC export contract SDWRF the HOC domestic contract for coefficients of relative risk aversion between 0 and 1 for the base scenario, scenario 1, and scenario 2.

The third objective of this study is to determine the potential for adding HOC to a corn/soybean rotation for various levels of risk aversion. The crop mix which maximizes the CE of per acre returns to unpaid labor, land and machinery was found for relative risk aversion coefficients (RRAC) ranging from 0 to 5. The CE maximizing crop mix for the base, scenario 1, and scenario 4 is a commodity corn/soybean rotation. However, HOC enters the crop mix for scenario 2, scenario 3 and scenario 5. Soybeans compose 50% of the crop rotation for all scenarios, so only the proportion of commodity corn and HOC planted per acre are displayed. The CE maximizing crop mix for scenario 2 is plotted in Figure 2. For RRAC's between 0-0.75, the CE maximizing crop mix is HOC export/soybeans. The CE maximizing crop mix is HOC export/HOC domestic/soybeans for RRAC's between 0.80-0.90, and the CE maximizing crop mix is corn/HOC export/soybeans for RRAC's between 0.90-5.

The CE maximizing crop mix when yields are increased by 20% (scenario 3) is presented in Figure 3. For RRAC's between 0-0.20, the CE maximizing crop mix is HOC export/soybeans. The HOC domestic contract enters the crop mix for RRAC's between 0.20-1.75 and the crop mix is corn/HOC export/HOC domestic/soybeans for RRAC's between 1.75-2.20. The CE maximizing crop mix for RRAC's between 2.20-5.0 is corn/HOC export/soybeans.

When both prices and yields are increased, the HOC export contract does not enter the CE maximizing crop mix (Figure 4). When RRAC's are between 0-0.30, the crop mix is HOC domestic/soybeans. Commodity corn enters the crop mix for RRAC's between 0.30-1.25. For RRAC's between 1.25-5, corn/soybeans is the CE maximizing crop mix and HOC is not produced.

Conclusions

A stochastic simulation model is used to study the risks and returns of producing high oil corn under both an export market and domestic market buyer's call contract. Corn and soybean yields and prices were drawn from a multivariate empirical distribution and oil content is drawn from a univariate empirical distribution. Non-parametric simulation is used to model the risk for the buyer's call contract.

The simulation results indicate that high oil corn under an export contract may be competitive if a hybrid with a low yield drag is planted. However, producers must be willing to accept greater uncertainty with respect to yields and prices to achieve the higher returns from HOC production. In addition, the profits from HOC production may begin to erode over time as more producers adopt HOC. The premium structure for HOC has been eroding somewhat over the last several years. The trend to lower premiums is likely to continue as the production of HOC becomes commoditized. Therefore, producers must carefully weigh the benefits of producing HOC versus No. 2 corn each year as new premiums are announced.

Future simulations will consider reduced oil content variability. Agronomists at Optimum Quality Grain, L.L.C., believe that oil content has less variability than suggested by test plot data (Kaplan). The potential for using hedge-to-arrive or basis contracts to reduce basis risk will be also analyzed. Finally, future analysis should account for the increased costs associated with producers having to identity preserve the HOC. Preliminary discussions have indicated that this cost maybe significant enough to deter adoption by some producers.

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Table 1. Summary Statistics of Data Used in the Stochastic Simulation Model.

	Mean	Std. Dev.	Min	Max
High Oil Corn Yield (bu./acre) [1]	129.5	20.6	107.0	177.5
No. 2 Corn Yield (bu./acre) [1]	142.8	19.9	116.0	197.0
High Oil Corn Oil Content (%)[1]	7.2 %	0.6 %	6.2 %	8.6 %
Indiana Corn Yield (bu./acre) [2]	113.5	11.3	94.9	132.0
Indiana Soybean Yield (bu./acre) [2]	36.9	3.9	30.5	43.2
Indiana Corn Price ($/bu.) [2]	$2.49	0.48	1.55	3.77
Indiana Soybean Price ($/bu.) [2]	$6.22	0.82	4.94	7.73
Gulf Corn Price ($/bu.) [3]	$2.84	0.49	1.83	4.30

1. Data from Ohio State University Extension, 1995-1999.
2. Data from Indiana Agricultural Statistics Service, 1972-1999.
3. Data from USDA ERS Feed Grain Yearbook.

Table 2. Correlation Coefficients and p-values for Multivariate Empirical Distributions.

	Corn Price	Soybean Price	Gulf Price	Corn Yield	Soybean Yield
Corn Price	1.0000	0.6011 [1] (0.0009)	0.9889 (0.0001)	-0.5690 (0.0020)	-0.3525 (0.0714)
Soybean Price		1.0000	0.5951 (0.0011)	-0.4619 (0.0044)	-0.3739 (0.0547)
Gulf Price			1.0000	-0.5312 (0.0044)	-0.3028 (0.1247)
Corn Yield				1.0000	0.7124 (0.0001)
Soybean Yield					1.0000

1. The top number is the correlation coefficient and the p-value is in parentheses.

Table 3. Description of Scenarios Simulated.

	Base	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Soybean Price ($/bu.)	$4.90	4.90	4.90	4.90	6.22	6.22
Corn Price ($/bu.)	$1.80	1.80	1.80	1.80	2.49	2.49
Gulf Corn Price ($/bu.)	$2.05	2.05	2.05	2.05	2.84	2.84
Corn Yield (bu./acre)	113.5	113.50	113.50	136.20	113.50	136.20
Soybean Yield (bu./acre)	36.9	36.90	36.90	44.28	36.90	44.28
HOC Yield drag (%)	9%	2%	2%	2%	2%	2%
HOC Seed Cost ($/acre)	$45.75	45.75	40.13	40.13	40.13	40.13

Table 4. Return to Unpaid Labor, Land, and Machinery for the Deterministic Model ($/acre).

	HOC Export	HOC Domestic	Corn	Soybeans
Base [1]	$58.70	52.50	70.55	114.78
Scenario 1	72.39	65.71	70.55	114.78
Scenario 2	78.01	71.34	70.55	114.78
Scenario 3	116.34	108.33	105.80	152.13
Scenario 4	121.15	146.12	136.38	145.40
Scenario 5	168.10	198.07	184.80	188.88

[1.] Return to unpaid labor, land and machinery for the scenarios described in Table 3.

Table 5. Summary Statistics for Return to Unpaid Labor, Land and Machinery for the Stochastic Simulation Model ($/acre) [1].

	Mean	Std. Dev.	Max.	Min	25th Percentile	75th Percentile
			Base [2]			
No. 2 Corn	$78.32	25.65	187.05	10.60	68.99	92.07
Soybeans	118.41	18.35	164.44	61.97	107.36	130.58
HOC Export [3]	60.20	27.97	175.88	-17.23	47.48	78.10
HOC Domestic [3]	59.84	28.11	195.70	-20.39	48.62	75.53
			Scenario 1			
No. 2 Corn	78.32	25.65	187.05	10.60	68.99	92.07
Soybeans	118.41	18.35	164.44	61.97	107.36	130.58
HOC Export	74.00	30.12	198.58	-9.38	60.30	93.28
HOC Domestic	73.61	30.27	219.92	-12.79	61.53	90.51
			Scenario 2			
No. 2 Corn	78.32	25.65	187.05	10.60	68.99	92.07
Soybeans	118.41	18.35	164.44	61.97	107.36	130.58
HOC Export	79.63	30.12	204.21	-3.76	65.93	98.90
HOC Domestic	79.24	30.27	225.55	-7.16	67.16	96.13
			Scenario 3			
No. 2 Corn	115.13	30.78	245.60	33.86	103.93	131.62
Soybeans	156.49	22.02	211.73	88.77	143.23	171.09
HOC Export	117.92	35.81	267.77	18.21	101.84	140.95
HOC Domestic	117.81	36.33	293.38	14.13	103.31	138.08
			Scenario 4			
No. 2 Corn	135.49	42.17	316.22	27.96	104.36	158.94
Soybeans	146.45	28.63	231.81	71.27	126.82	162.57
HOC Export	114.22	44.22	365.07	2.12	89.90	136.24
HOC Domestic	134.95	48.02	367.03	13.59	103.37	162.82
			Scenario 5			
No. 2 Corn	183.72	50.61	400.60	54.69	146.37	211.87
Soybeans	190.14	34.36	292.57	99.92	166.58	209.49
HOC Export	159.42	52.95	460.81	25.27	130.52	185.74
HOC Domestic	184.66	57.62	463.16	39.03	146.77	218.10

1. Summary statistics based on simulations using 1800 iterations per scenario.
2. Scenario parameters are described in Table 3.
3. HOC Export and HOC Domestic represent high oil corn produced under an export and domestic market buyer's call contract, respectively.

Table 6. Summary of the Stochastic Dominance Pair-wise Comparison of the Distributions of Returns to Unpaid Labor, Land and Machinery.

			Coefficient of Absolute Risk Aversion [1]				
			0.00	0.01	0.02	0.03	0.04
			Base [3]				
C-SB [4]	-	sb [5]	sb	sb	sb	sb	sb
SB-HOCE	-	sb	sb	sb	sb	sb	sb
SB-HOCD	-	sb	sb	sb	sb	sb	sb
C-HOCE	c	c	c	c	c	c	c
C-HOCD	-	c	c	c	c	c	c
HOCE-HOCD	-	-	hoce	hocd	hocd	hocd	hocd
			Scenario 1				
C-SB	-	sb	sb	sb	sb	sb	sb
SB-HOCE	-	sb	sb	sb	sb	sb	sb
SB-HOCD	-	sb	sb	sb	sb	sb	sb
C-HOCE	-	c	c	c	c	c	c
C-HOCD	-	c	c	c	c	c	c
HOCE-HOCD	-	-	hoce	hocd	hocd	hocd	hocd
			Scenario 2				
C-SB	-	sb	sb	sb	sb	sb	sb
SB-HOCE	-	sb	sb	sb	sb	sb	sb
SB-HOCD	-	sb	sb	sb	sb	sb	sb
C-HOCE	-	-	c	c	c	c	c
C-HOCD	-	-	c	c	c	c	c
HOCE-HOCD	-	-	hoce	hocd	hocd	hocd	hocd
			Scenario 3				
C-SB	-	sb	sb	sb	sb	sb	sb
SB-HOCE	-	sb	sb	sb	sb	sb	sb
SB-HOCD	-	sb	sb	sb	sb	sb	sb
C-HOCE	-	-	hoce	c	c	c	c
C-HOCD	-	-	hocd	c	c	c	c
HOCE-HOCD	-	-	hocd	hocd	hocd	hocd	hocd
			Scenario 4				
C-SB	-	sb	sb	sb	sb	sb	sb
SB-HOCE	-	sb	sb	sb	sb	sb	sb
SB-HOCD	-	sb	sb	sb	sb	sb	sb
C-HOCE	-	c	c	c	c	c	c
C-HOCD	-	c	c	c	c	c	c
HOCE-HOCD	hocd	hocd	hocd	hocd	hocd	hocd	hocd
			Scenario 5				
C-SB	-	sb	sb	sb	sb	sb	sb
SB-HOCE	-	sb	sb	sb	sb	sb	sb
SB-HOCD	-	sb	sb	sb	sb	sb	sb
C-HOCE	-	c	c	c	c	c	c
C-HOCD	-	-	c	c	c	c	c
HOCE-HOCD	hocd	hocd	hocd	hocd	hocd	hocd	hocd

1. Lower and upper coefficients of absolute risk aversion used in stochastic dominance with respect to a function.
2. FSD and SSD represent first and second degree stochastic dominance, respectively.
3. Scenario parameters defined in Table 3.
4. C, SB, HOCD, and HOCE represent No. 2 corn, soybeans, high oil corn domestic buyer's call contract, and HOC export buyer's call contract, respectively.
5. The dominant distribution for the pair-wise stochastic dominance comparison. A letter represents the dominant crop distribution and a hyphen represents no stochastic dominance. In this case, the letters sb signifies that the soybean distribution second-degree stochastically dominates the corn distribution for the base scenario.

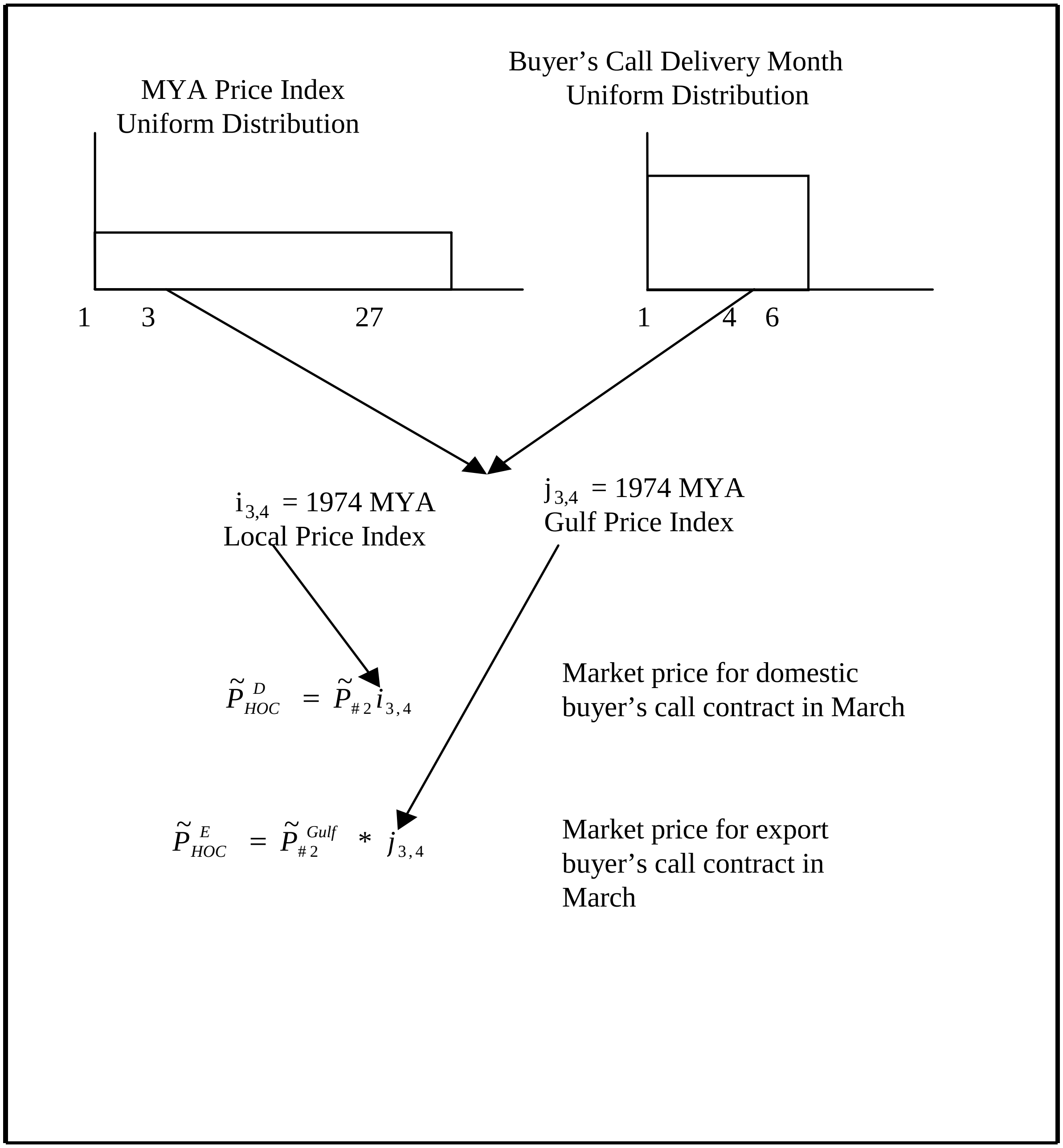

Figure 1. Graphical Depiction of the Non-parametric Simulation Approach for Simulating Buyer's Call Delivery Month Domestic and Export Market Prices

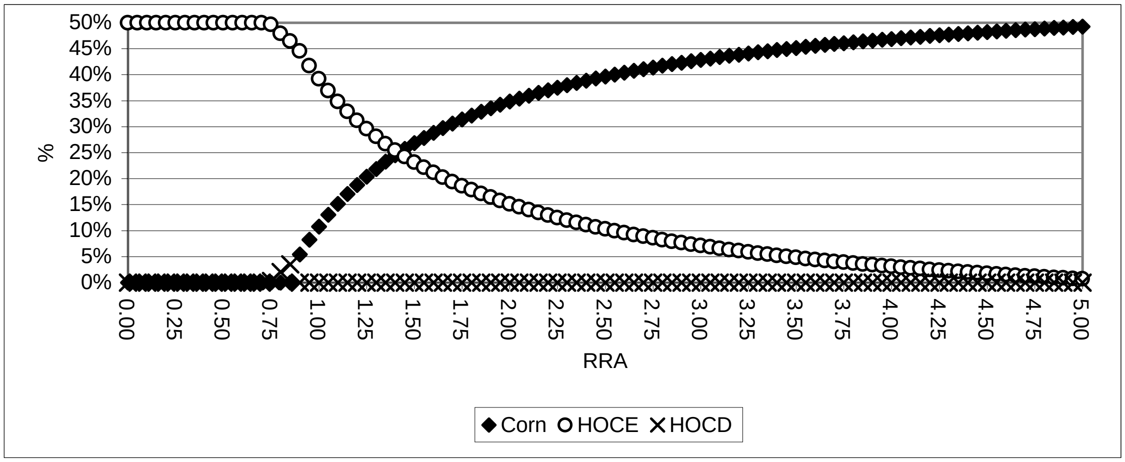

Figure 2. CE Maximizing Corn Crop Mix for Scenario 2 where Soybeans Compose 50% of the Rotation.

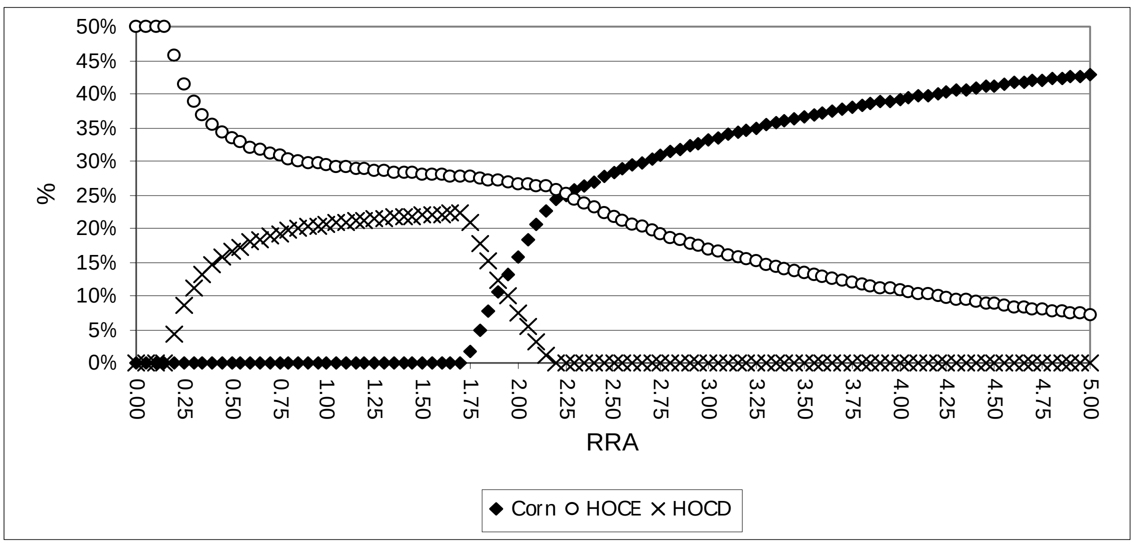

Figure 3. CE Maximizing Corn Crop Mix for Scenario 3 where Soybeans Compose 50% of the Rotation.

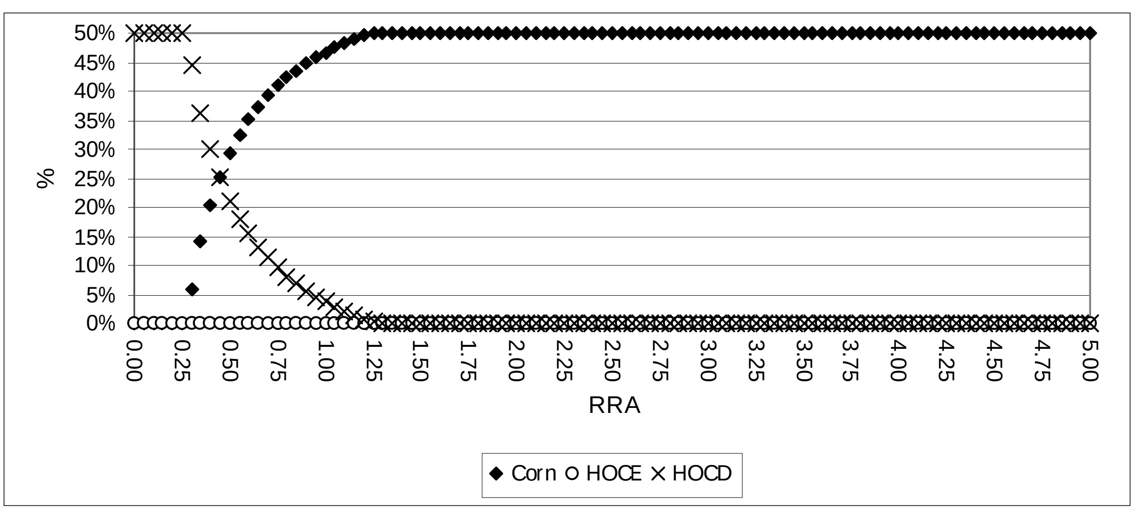

Figure 4. CE Maximizing Corn Crop Mix for Scenario 5 where Soybeans Compose 50% of the Rotation.