Profitability of Non-Irrigated Corn and Grain Sorghum Under Yield and Price Uncertainty

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Planting decisions by farmers are made without full information on the amount and timing of growing season rainfall or the prices the farmer will receive for their crop. For dryland farmers in the Great Plains, the choice between planting corn and grain sorghum is driven by both the relative prices between crops and the planted crop's performance under potential rain and temperature conditions (Staggenborg, Dhuyvetter, and Gordon 2008).

Grain sorghum's characteristic of drought tolerance allows it to be grown in areas where precipitation is erratic and water stress is expected, as it is in portions of Western Kansas, Oklahoma, and the Texas panhandle. However, in the past 15 years, improvements in the drought tolerance of newer corn hybrids have led to the number of non-irrigated corn acres planted in Kansas to triple, increasing the figure to 3.2 million acres (USDA-NASS 2012). There has been a corresponding drop in non-irrigated sorghum planted acres over the same time period, from 3.4 million to 2.6 million acres.

While drought tolerance is a primary consideration for dryland farms, it is possible that irrigated farms in some parts of the Great Plains will face decisions concerning yield performance under water stress in the near future. The primary water source for Nebraska, Western Kansas, and the panhandles of both Texas and Oklahoma is the Ogallala Aquifer. Estimates of declining water levels in the aquifer may create future limitations on the availability of water for irrigation and subsequently lead to a change in cropping patterns (McGuire 2007).

The objective of this study is to analyze profitability of both dryland corn and grain sorghum under yield and price uncertainty. Data on historical yields, price relationships, and weather conditions are used in conjunction with forward-looking estimates of production costs and commodity prices to determine the distribution of profits that could be expected for each crop enterprise. Accounting for both expected returns and the associated risk, the cumulative density functions of profits from each enterprise are compared in a stochastic dominance framework. Results indicate that dryland corn has greater profit potential, when risk is considered, than grain sorghum. This result corresponds with the observed switch in planted acres from grain sorghum to corn over the past 15 years.

Literature Review

Several studies have been conducted addressing both the yield and price risk associated with planting decisions. Chavas, Posner, and Hedtcke (2009) focus on the relative profitability and risk exposure of organic and conventional cropping systems in Wisconsin. They evaluate the expected profits of each farming system based on the moments of the profit function: the mean, variance, and skewness. Estimated parameters from these moments are used to determine a cost of risk that, when subtracted from the mean, gives a measure called a certainty equivalent. This is a single measure that evaluates both the average returns and the cost of risk.

A related study by Stanger, Lauer, and Chavas (2008) used the method of stochastic dominance to rank different cropping systems. This method requires making assumptions about the risk aversion of a farmer and using the cumulative density function of the profit distribution to determine the most efficient cropping system. Delbridge et. al. (2011) followed this approach for evaluation of long-term organic and conventional cropping systems in Minnesota. They estimated and ranked the relative risk of net return distributions for each system, acknowledging that the stochastic dominance method does not impose any requirements on the form of the profit probability distributions.

Methods and Data

The uncertainty facing a farmer when they make their planting decisions stems from several sources: input prices, weather conditions, disease or weed outbreaks, and harvest prices are all variable factors that can affect the profitability of one crop versus another. While forward contracting can reduce the variability of input costs and harvest prices (usually at a cost to the grower), other factors affecting yield outcomes simply cannot be controlled. The goal of the analysis presented in this study is to provide an estimate of the relative profitability of corn and grain sorghum and the uncertainty around that estimate. Once characterized, the profitability distributions can be used to assess the impacts of changing market conditions affecting prices, crop insurance, or limited water availability.

Yield Curve Estimation

The analysis begins with estimation of a yield function, which can be used to simulate a distribution of yield outcomes under uncertain weather conditions. The yield regression is defined as follows

(1) $$yield_t^i = f\{maxtemp_t, precip_t, year, GS_t, inputs_t^i\}$$

where the observed yield of crop *i* in year *t* is a function of the maximum growing season recorded temperature ($maxtemp_t$); the total growing season rainfall ($precip_t$); the year when the yield was observed ($year$); the length of the growing season (GS_t); and a vector of crop-specific inputs including nitrogen, phosphorous, and potassium ($inputs_t^i$). The parameters of the yield functions for dryland corn and grain sorghum are listed in table 1. The data used for the estimation of equation (1) are K-State field test plots from 1996 to 2009 located in Western Kansas.

Estimation of the parameters of the yield regression allows us to predict yield, given values for each parameter. The primary sources of variability in the yield regression, which cannot be affected by the farmer, are temperature and rainfall. To simulate this variability, historical observations of the maximum recorded temperature and total rainfall over the course of the growing season at field test plots in Western Kansas were obtained. These data were plotted and a kernel density estimator was used to characterize their distribution. Temperature and rainfall are not independent of each other. Therefore, the kernel density estimates include a correlation coefficient obtained from the observed temperature and rainfall data. Temperature was estimated to be normally distributed with a mean of 81.37 degrees and a standard deviation of 2.04 degrees. Rainfall follows a Gamma distribution with a mean of 0.445, a shape parameter equal to 12.417 and a scale parameter of 0.036. The coefficient of correlation is -0.75.

Yield and Price Simulation

Simulation of the distribution of profits for corn and sorghum begins with performing repeated draws of the random variables. Since rainfall and temperature are not independent random variables, the process of drawing random realizations of these parameters requires the use of a copula. There are a large number of copula families presented in the literature (Nelson 2006), but the one used here is the Gaussian or normal copula. The Gaussian copula takes the following form

(2) $C(u_1 u_2; \theta) = \Phi_2(\Phi^{-1}(u_1), \Phi^{-1}(u_2); \theta)$

where $\Phi$is the distribution function of the univariate standard normal distribution, Φ^{-1} is the inverse of the standard normal distribution and $\Phi_2(x_1, x_2; \theta)$ is the standard bivariate normal distribution with correlation parameter $\theta \in (-1,1)$. A random sample of 100,000 draws was pulled from a standard normal distribution. These draws were transformed into realizations from the correlated normal (temperature) and Gamma (rainfall) distributions using the Gaussian copula.

The other primary driver of variability in profits is the price received by the farmer. Simulation of the expected price distribution for corn uses an estimate of the mean and variance of the 2013 December futures price for corn (Hilker 2013). This is the nearby contract for Kansas corn growers who harvest in early October. The distribution is assumed to be normal with a mean of $6.26/bu and a standard error equal to $1.54/bu.

With no futures contract for grain sorghum, a corollary price expectation does not exist. However, corn and sorghum prices typically fall within a small range of each other due to the nature of these two grains as substitutes in livestock feed and biofuels. We use a historical price ratio of corn to sorghum prices from several Western Kansas locations to determine a price ratio distribution. The distribution is assumed to be normal with a mean of 1.13 and a standard deviation of 0.17. As with the rainfall and temperature distributions, the simulation is performed using 100,000 independent draws from the corn price and price ratio distributions. For every pair of corn price and ratio draws, the sorghum price is calculated.

Profit Distributions

Calculations of the profitability of the corn and sorghum enterprises are made using cost of production estimates from the K-State Farm Management Guides (2013). These guides are updated annually to reflect the most current information on chemical and fertilizer prices, machinery costs, and land values. The budgets are based on best management practices for the area they cover. The budgets for non-irrigated corn and sorghum are given in table 2.

To compare risk between the corn and sorghum enterprises, we apply a stochastic dominance framework to the cumulative density functions of each profit distribution. Two types of stochastic dominance are considered: first-degree stochastic dominance (FDSD) and second-degree stochastic dominance (SDSD). Stochastic dominance is based on two assumptions of people's behavior. The first is that people prefer more to less (in our case more profit) and the second is that most people prefer less risk (Lambert and Lowenberg-DeBoer 2003). First-degree stochastic dominance indicates that an alternative is preferred over another because it provides a larger outcome at every probability level. A sufficient condition for a crop enterprise, with cumulative density function A, to first-order dominate another crop enterprise, with cumulative density function B, is

(3) $A(x) \leq B(x)$, for all x,

with the inequality strictly holding over some domain of x (Stanger, Lauer, and Chavas 2008). Graphically, this would mean that the CDF of crop enterprise A would be located entirely to the right of the CDF of crop enterprise B.

Second-degree stochastic dominance also assumes people prefer more profits to less and that people are risk averse. A sufficient condition for SDSD is

(4) $\int_{-\infty}^{y} A(x)dx \leq \int_{-\infty}^{y} B(x)dx$, for all y,

with the inequality holding strictly over some domain of y (Stanger, Lauer, and Chavas 2008). Graphically, if the CDF's of the two crop enterprises cross, first order stochastic dominance does not hold and the CDF's are evaluated according to equation (4) for SDSD.

Results and Discussion

For each yield and price outcome simulated by random draws from the distributions described previously, a profit calculation is made. Histograms of the profit outcomes are shown in figures 1 and 2 for corn and grain sorghum, respectively. Overlaid on the histograms is an estimated lognormal density curve. Comparison of the means of these distributions suggests that corn at a mean profit of $170 per acre, while sorghum profits average $120 per acre.

The CDF's of the profit distributions for corn and grain sorghum are shown in figure 3. First order stochastic dominance does not hold for either cumulative density function. However, visual inspection reveals the corn profit cumulative density function second-order dominates the grain sorghum cumulative density function. This implies that while grain sorghum has agronomic properties that lead to good yield performance in dryland production conditions, the potential profits from growing non-irrigated corn are larger and have a higher probability of occurring.

These results help explain the downward trend of sorghum acres and the increase in planted corn acres. Whether or not these trends continue will depend on future changes in the relative yield and price variability. Not considered in this analysis are the impacts of either crop insurance or premiums derived from changes in biofuel subsidies. For example, if grain sorghum becomes classified as a preferred feedstock for ethanol, there may be a resulting price premium that would change its profitability distribution relative to corn.

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Table 1. Estimated Parameters of Corn and Grain Sorghum Yields

	Coefficient	Standard Deviation	p-value
Corn			
Intercept	620.680	711.610	0.383
maxtemp	-3.277	1.095	0.003
precip	128.316	18.444	0.000
year	-0.186	0.342	0.586
GS	0.157	0.132	0.234
N	0.256	0.139	0.067
N2	-0.001	0.001	0.143
P	0.258	0.094	0.007
Number of Observations =	694		
Grain Sorghum			
Intercept	2162.616	373.112	0.000
maxtemp	0.995	0.575	0.084
precip	114.669	7.998	0.000
year	-1.111	0.184	0.000
GS	0.520	0.052	0.000
N	-2.502	0.260	0.000
N2	0.019	0.002	0.000
P	0.204	0.069	0.003
Number of Observations =	1,079		

Table 2. K-State Crop Enterprise Budgets for 2013

	Corn	Grain Sorghum
Income Per Acre		
A. Yield per acre	80	45
B. Price per bushel	$6.49	$5.87
C. Net government payment	$12.20	$8.13
D. Indemnity payments	$0.00	$0.00
E. Miscellaneous income	$0.00	$0.00
F. Returns/acre ((A x B) + C + D + E)	$531.40	$272.28
Costs Per Acre		
1. Seed	$69.80	$7.20
2. Herbicide	24.79	25.02
3. Insecticide / Fungicide	1.00	0.00
4. Fertilizer and Lime	73.91	48.90
5. Crop Consulting	0.00	0.00
6. Crop Insurance	0.00	0.00
7. Drying	0.00	0.00
8. Miscellaneous	5.50	5.50
9. Custom Hire / Machinery Expense	73.06	63.66
10. Non-machinery Labor	8.26	7.19
11. Irrigation		
a. Labor	0.00	0.00
b. Fuel and Oil	0.00	0.00
c. Repairs and Maintenance	0.00	0.00
d. Depreciation on Equipment / Well	0.00	0.00
e. Interest on Equipment	0.00	0.00
12. Land Charge / Rent	105.00	35.00
G. SUB TOTAL	$361.31	$192.46
13. Interest on 1/2 Nonland Costs	8.33	5.12
H. TOTAL COSTS	$369.64	$197.58
I. RETURNS OVER COSTS (F - H)	$161.76	$74.70

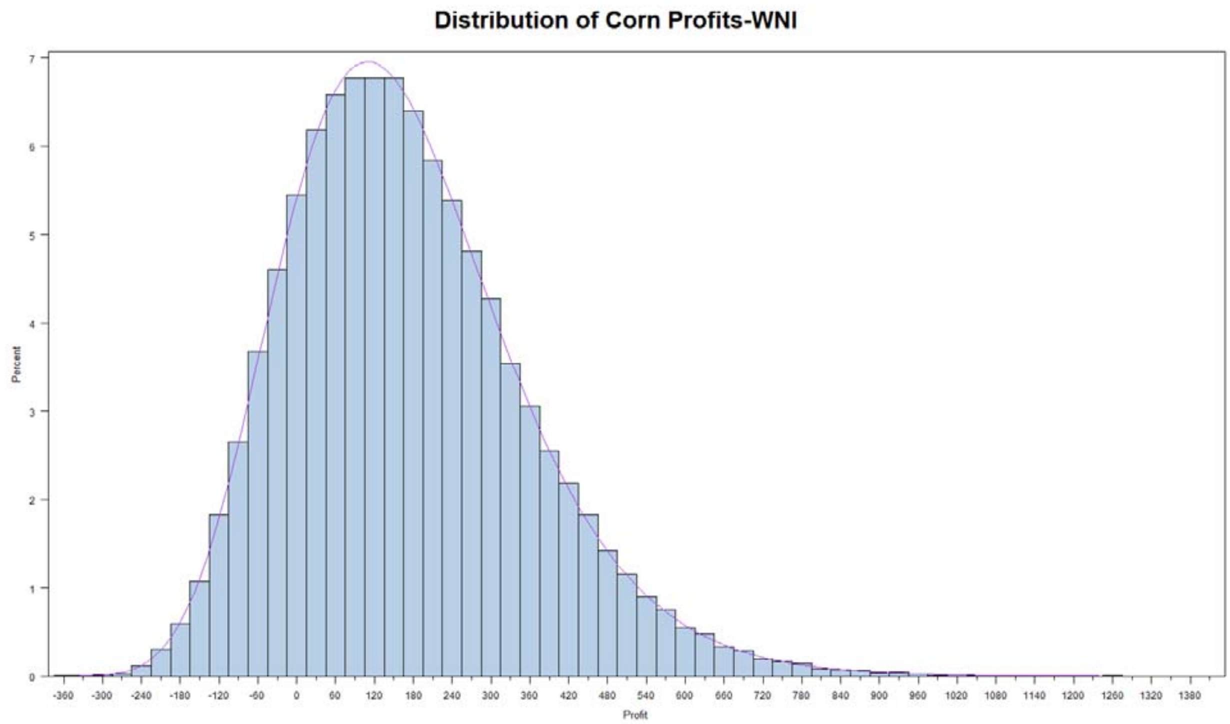

Figure 1. Distribution of Non-Irrigated Corn Profits

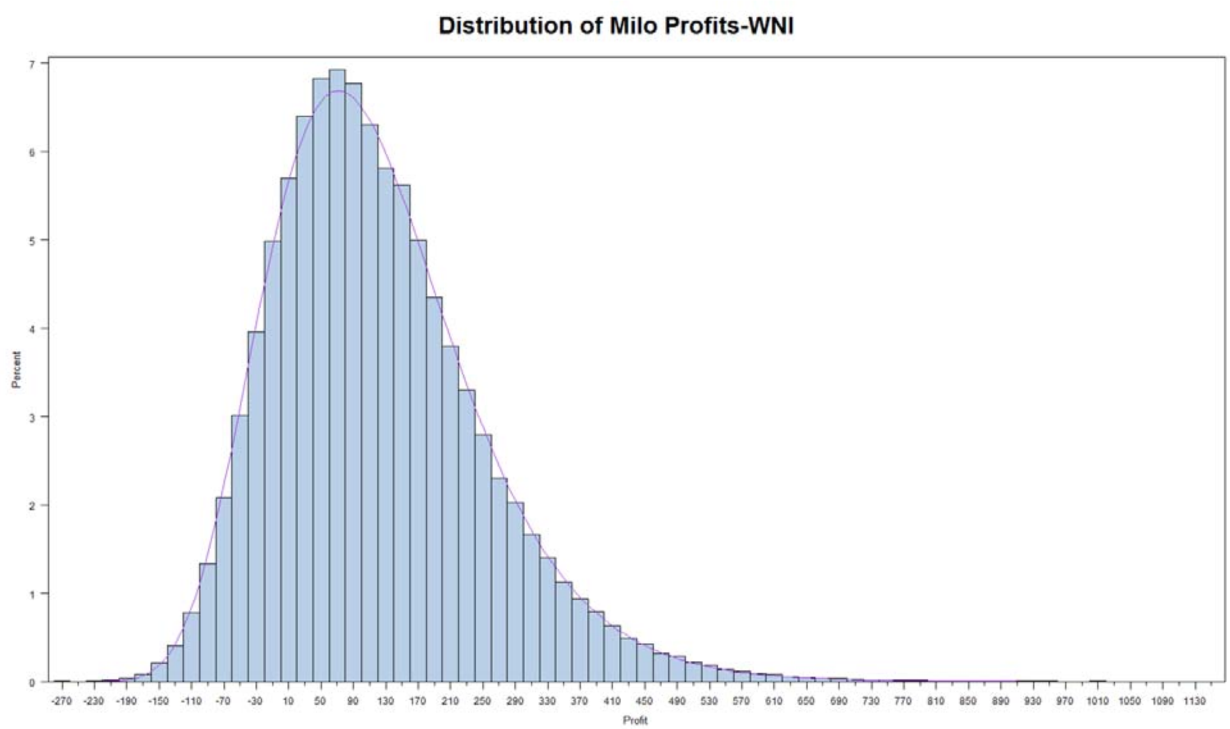

Figure 2. Distribution of Non-Irrigated Grain Sorghum Profits

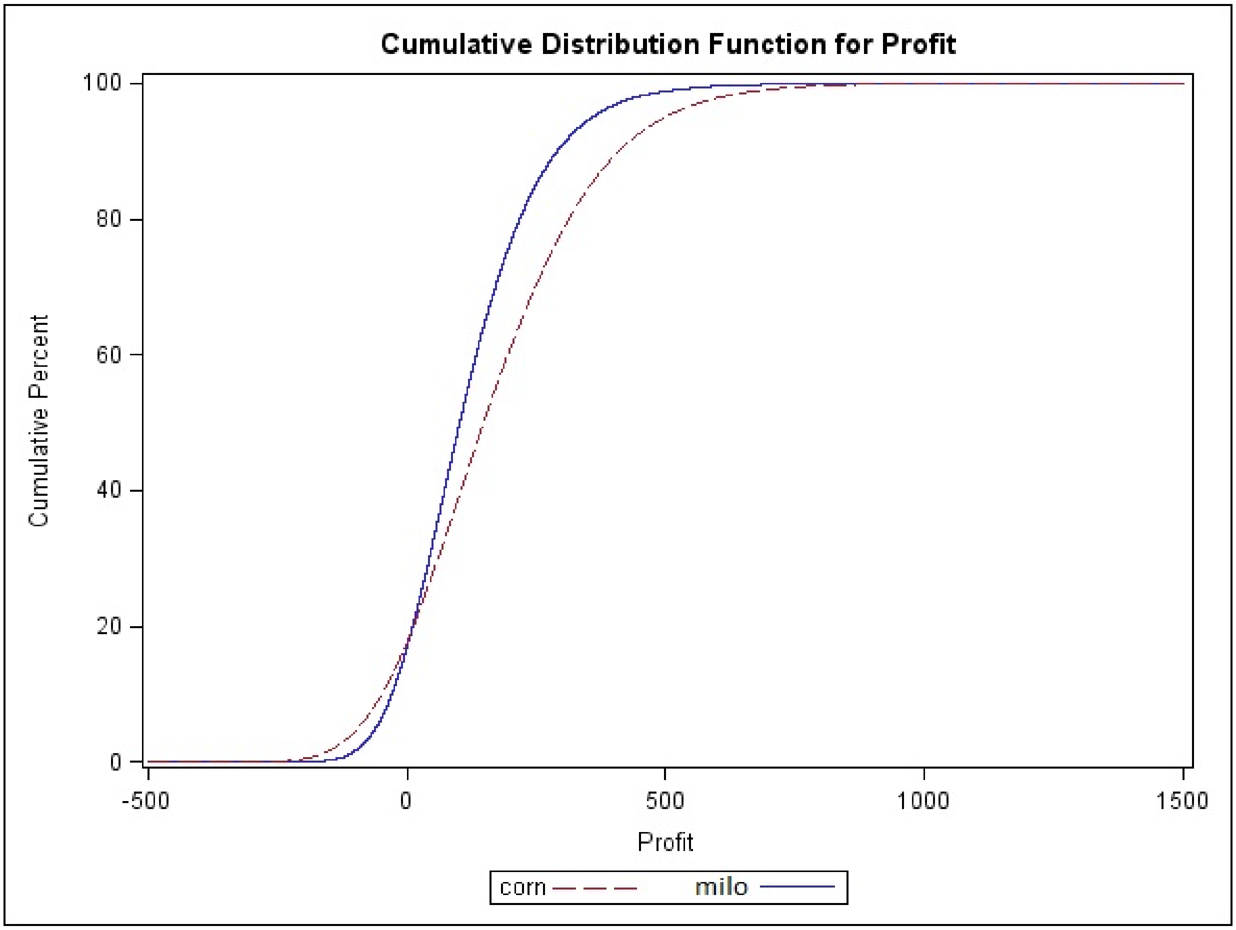

Figure 3. Cumulative Density Functions for Corn and Grain Sorghum Profits