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SHORT-RUN CORN - SOYBEAN PRODUCTION DECISIONS WITH VARIABLE ENERGY AND PRODUCT PRICES

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Midwestern corn-soybean farmers have approached the past few planting seasons facing input and output price relationships not previously experienced. These new relationships add complexity to short-run production decisions as the planting season draws near. Decisions must be made concerning fertilization rates and proportions of corn and soybeans to plant; furthermore, delays in the decisions are extremely costly due to the timeliness penalty associated with late plantings. These new price relationships and the forced action situation facing decision makers have created renewed interest in the impact of variable prices on input levels and output mix.

Energy shortages have been a principal culprit in adding to the complexity of the decision making. Rapidly rising nitrogen fertilizer prices have caused farmers to raise questions about optimum use levels on corn and have sent economists and agronomists scurrying to construct nitrogen response curves to test recommended application rates under these new prices (Black and Ferris, Forster and Rask, Hoeft and Siemens, and Raikes and Harris). Increased crop drying costs have added additional

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cost burden to corn production and along with the higher nitrogen costs have placed corn in a poorer competitive cost situation with soybeans (Raikes and Harris). Widely fluctuating corn and soybean prices add further complexity and uncertainty to production decisions involving these two crops. Not only has the level of prices changed dramatically, but over the past five years corn-soybean price ratios have fluctuated from 1.9 to 4.3 during the period prior to planting.

The purpose of this paper is to trace out the economic consequences of a series of price relationships on the optimum use of energy inputs (nitrogen fertilizer) and on the optimum combination of soybean and corn acreage under "typical" Ohio corn belt conditions. Three questions are posed in terms of short-run (single season) decisions.

1) How should nitrogen application rates be adjusted in response to changing nitrogen and corn price relationships?
2) How should corn and soybean acreage be adjusted as nitrogen and fuel drying costs increase?
3) What proportion of corn-soybean acreage should be planted to corn in order to obtain maximum returns under changing corn and soybean prices.

PROCEDURE

Three elements were crucial to answering the above questions. First, a farm level nitrogen response function had to be adopted from experimental data. Secondly, appropriate yield penalties were established to reflect the competitive importance of timeliness in the planting and harvesting of corn and soybeans. Finally, a benchmark or control farm situation was established from which to measure changes in the optimum levels of input use and output mix under alternative price relationships.

The benchmark situation was determined by synthesizing a "typical" farm situation. This situation was chosen by selecting a level of input usage and output mix which was representative of Ohio cash grain farms.[1/] The resource basis of the "typical" farm was determined by selecting that set of labor and machinery capacities which allowed the optimum input and output mix on a given cropland acreage to approximate the benchmark situation described below.

Nitrogen, corn, soybean and crop drying price changes were systematically introduced and profit optimization solutions determined for each new price relationship. The resulting fertilizer application rates and acreage determinations for corn and soybeans provided some notion of optimum responses to the dynamic price situation facing midwestern grain farmers.

The Benchmark Farm Situation

The "typical" farm situation was developed with the following assumptions:

[1/] Data from Duvick, et. al. and suggestions from farm management personnel at Ohio State University were used to establish this situation.

1) The "typical" farm would maximize returns by planting one-half of the corn-soybean acreage to corn and the other half to soybeans under "normal" price relationships. These prices were selected to be $2.50 per bushel for corn and $6.00 per bushel for soybeans.[2/] Other "normal" prices were $.20 per pound for nitrogen fertilizer and drying charges of $.01 per point of moisture removed.

2) Labor and machinery capacities were sufficient to complete corn and soybean planting during a five week period from late April to the first of June. Similarly, harvesting was completed during an eight week period from late September to mid-November.[3/]

3) Planting and harvesting timeliness penalties on yields were assumed. Thus, as more acreage is devoted to either corn or soybeans in response to price changes, some yield loss results because of untimely planting and harvesting operations.[4/]

4) The "typical" farm was assumed to maximize returns to nitrogen on corn at application rates of 125 pounds and yields of 105 bushels per acre. Maximum soybean yields were assumed at 35 bushels per acre.

[2/] These prices are somewhat above the absolute levels experienced in the late 1960's and early 70's, but do reflect the relative price relationship of soybeans to corn (2.4 to 1) during this period.

[3/] A 460 acre farm was assumed for the analysis. However, farm size is not crucial to the analysis since machinery and labor capacities were adjusted to give the desired optimum combination of corn and soybean (50-50) under the normal prices assumed.

[4/] In this situation, both crops compete for labor and machinery capacities during key periods of the planting and harvesting seasons.

Corn yields and optimum nitrogen application rates were adjusted from these levels to reflect changing prices. These new levels were established by assuming a farm level response function similar to experimental data but at a somewhat lower level.[5] A summary of these and other assumptions are included in Table 1. Specific optimum nitrogen application rates and associated corn yields are presented in Table 2.

Two models were used to analyze this "typical" farm situation. These two models are the Corn-Soybean Guide Linear Programming Model and the Purdue Crop Budget.[6] Both these programs are linear programming models which maximize the returns above variable costs for a corn-soybean farm situation. Both models include a number of activities for land preparation in alternative time periods, corn production and soybean production activities which allow for alternative corn planting and harvesting sequences. Key restrictions in the models pertain to the total number of acres which may be planted in a planting period, the total number of acres which may be harvested in a harvesting period, and the number of acres of a particular crop which may be planted or harvested in a time period. The differences in

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[5] Several corn belt studies (Black and Ferris, Forster and Rask, and Hoeft and Siemens) have demonstrated experimental nitrogen response curves that maximize physical corn production at between 140 and 175 bushels per acre, depending on soil type. The "typical" nitrogen application rates and corn yield levels assumed above were based on average yields and nitrogen use levels in corn belt areas of Ohio.

[6] Michigan State University Teleplan Program #18 and Purdue Crop Budget Model B-9.

the model are largely those of the degree of detail in the model. Generally, the Purdue Crop Budget Model is the more complete, but its computational requirements are also greater.

The Corn-Soybean Guide Linear Programming Model was used as the primary tool of analysis due to its relative ease of use and lesser computational requirements. The Purdue Crop Budget was used to verify these results.

RESULTS

The analysis investigates short-run planting decisions. In the short-run, one season for example, the complement of equipment, land and labor is fixed. The decisions to be made concern the proportion of corn and soybeans which will be planted in the current season using these fixed resources and the level of variable inputs to apply. The resulting distribution of land use and rate of input usage reflects the combined impact of both input and output price changes.

As the profit maximizer solves the first order conditions, the level of variable input and the combination of output are interdependent. For example, as nitrogen prices become higher, optimum nitrogen application rates decline, corn yield falls and returns per acre in corn are reduced. Thus, the competitive position of soybeans is improved, and a smaller proportion of the crop acreage is planted to corn. However, this change is mitigated somewhat by an opposite impact from yield penalties due to timeliness. As soybean acreage is increased, the planting and harvesting time is spread into less optimum yield periods, thus reducing soybean yields

TABLE 1

Assumed Conditions for "Typical" Ohio Corn-Soybean Farm Simulation

Characteristic	Assumption
Normal Prices	
Corn (per bushel)	$2.50
Soybeans (per bushel)	6.00
Nitrogen (per pound)	.20
Drying Fuel (per point of moisture removed)	.01
Variable Production Costs at Normal Prices (per acre)	
Corn	$103.20
Soybeans	66.50
Normal Crop Acreage	
Corn	50% of total
Soybeans	50% of total
Normal Planting Period	April 25 to June 1 (5 weeks)
Normal Harvesting Period	Sept. 27 to Nov. 15 (7 weeks)
Maximum Yields at Normal Prices	
Corn (bushels per acre)	105
Soybeans (bushels per acre)	35
Nitrogen Application at Normal Prices (pounds per acre)	125

Timeliness Yield Penalties for Corn and Soybeans

Planting Period	Harvesting Period: Sept. 27 - Oct. 3	Oct. 4-10	Oct. 11-17	Oct. 18 - Nov. 7	Nov. 8-28
	Percent Yield Reduction for Corn				
April 25 to May 10	10	0	1	2	12
May 11 - 18	18	8	9	10	20
May 19 - 26	100	16	17	18	29
May 27 to June 3	100	24	25	26	38
	Percent Yield Reduction for Soybeans				
May 19-26	0	5	12	32	--
May 27 to June 3	4	9	16	35	--
June 4-11	7	12	21	39	--
June 12-19	18	23	30	50	--

Price Ranges Tested

Corn (per bushel)	$2.00 to $4.00
Soybeans (per bushel)	4.00 to 8.00
Nitrogen (per pound)	$ .20 to $ .50
Drying Fuel (per point)	.010 to .30

TABLE 2

Assumed Optimum Nitrogen Application Rates and Corn Yield Levels on "Typical" Ohio Crop Farm

Price of Corn Per Bushel	Price of Nitrogen Per Pound			
	$ .20	$ .30	$ .40	$ .50
	Pounds of Nitrogen Per Acre			
$2.00	121	113	104	94
2.50	125	118	111	105
3.00	128	122	116	111
3.50	129	125	120	115
4.00	130	127	122	118
	Yield of Corn in Bushels Per Acre			
$2.00	103	100	96	91
2.50	105	102	99	97
3.00	106	104	101	99
3.50	107	105	103	101
4.00	107	106	104	102

* The response of corn yields to various levels of nitrogen applications was adapted from data furnished by L. N. Shepherd, Department of Agronomy, The Ohio State University.

somewhat. Conversely, corn acreage is reduced, allowing more to be planted and harvested in the optimum period, thus increasing yields.

The results of the analysis for the "typical" farm situation are summarized in Table 3. This table shows the optimum proportion of corn and soybean ground planted to corn under alternative corn, soybean, and nitrogen price combinations. With soybeans at $6.00 per bushel at the farm level, corn at $2.50 per bushel and nitrogen at $.20 per pound, this "typical" farmer finds it most profitable to split his corn-soybean ground evenly between the two crops (the assumed benchmark conditions).

The impact of high nitrogen prices on optimum corn acreage is readily apparent from Table 3. If we confine our attention to soybean prices in the $5.00 to $7.00 per bushel range and corn prices in the $2.50 to $3.00 per bushel range, each $.10 per pound increase in the price of nitrogen results in the optimum proportion of corn decreasing by 6.3 percent of the total cropland acreage. At $2.50 corn, $6.00 soybeans and $.20 nitrogen, about 50 percent of the cropland is planted in corn. As the nitrogen price increases to $.30 per pound, 40 percent of the cropland is planted to corn, and at nitrogen price of $.50 per pound a decrease in corn acreage to approximately 30 percent of the total is indicated.

Table 3 also illustrates the effect of changing corn and soybean prices on optimum acreages. With the nitrogen price at $.20 per pound, optimum plantings are quite sensitive to changes in corn and soybean prices. With $2.50 corn and $6.00 soybeans, 50 percent of the cropland is planted in each crop. As prices change to $3.00 corn and $6.00 soybeans, the op-

TABLE 3

Percent of Corn and Soybean Cropland Planted to Corn
On A "Typical" Ohio Farm Under Alternative Prices
For Nitrogen, Corn, and Soybeans

Nitrogen Price/lb.	Corn Price/bu.	Soybean Price ($/bu.) 4.00	5.00	6.00	7.00	8.00
		-- Percent of Cropland in Corn --				
$ .20	$2.00	50*	40*	30	20	20
	2.50	85	50	50	40	40
	3.00	100	85	60	50	40
	3.50	100	100	85	75	50
	4.00	100	100	100	85	75
$ .30	2.00	35*	35*	20	20	0
	2.50	50*	50	40	40	30
	3.00	85	75	50	50	40
	3.50	100	85	85	60	50
	4.00	100	100	85	85	75
$ .40	2.00	30*	30*	20*	0	0
	2.50	50*	40	40	30	20
	3.00	85	75	50	40	40
	3.50	100	85	75	50	50
	4.00	100	100	85	75	60
$ .50	2.00	0*	0*	0*	0	0
	2.50	50*	35*	30*	20	20
	3.00	75*	50	50	40	40
	3.50	100	85	60	50	40
	4.00	100	100	85	75	50

* Optimum solutions did not fully utilize all crop acreage. Because of late planting and/or harvesting, the timeliness penalties forced the marginal value product to be less than the marginal input cost on a portion of the acreage.

timum corn acreage increases to 60 percent of the total. Similar percentage acreage changes can be noted at other price levels for corn, soybeans and nitrogen. While these changes are significant, it is important to note that within most expected price relationships both corn and soybeans are produced. This results largely from the impact of yield losses due to timeliness factors for both harvesting and planting. Due to the timeliness losses which occur as a higher percentage of cropland is devoted to either corn or soybeans, substantial deviations from normal corn-soybean price relationships are necessary before all of the cropland is planted to either corn or soybeans. This would indicate that short-run adjustments to price changes may be considerably less than long run adjustments where farmers would have an opportunity to change machinery-land relationships and thus perform tasks in a more timely nature.

The impact of changing corn drying costs was also tested. The effect of these changes on corn-soybean acreage balance was minimal as optimum solutions held over a wide range of drying charges. Undoubtedly some of this rigidity was due to the linear nature of the model; however, it is apparent that within recent corn and soybean price ranges, drying costs will not materially affect optimum corn acreage.

A sensitivity analysis was conducted to determine the impacts of variations in planting and harvesting technical efficiencies on the optimum corn-soybean balance acreages. It appeared that the results in Table 3 were similar for farms whose technical production efficiencies deviated by approximately 20 percent from those technical efficiencies used in the analysis.

CONCLUSIONS

The preceding discussion has provided some clues concerning the three questions posed at the beginning of this paper. The farm situation analyzed in this study has presented some insights into the effect of nitrogen prices on the optimum nitrogen application rates, the effect of nitrogen prices on the proportion of cropland to be planted in corn, and the effect of corn and soybean prices on optimum acreages of corn and soybeans. Significantly, the computed changes in crop acreages were insensitive to small changes in the assumed technical production efficiencies. This insensitivity would indicate that farmers under a broad range of conditions should make similar adjustments in response to price changes.

Adjustments in Nitrogen Levels

At recent price ranges of $2.50 to $3.50 per bushel for corn and $.20 to $.40 per pound for nitrogen, application rates of nitrogen on corn are not greatly affected. Optimum nitrogen application rates differed by 15 percent at the extremes of these ranges ($2.50 corn and $.40 nitrogen versus $3.50 corn and $.20 nitrogen). Furthermore, yields differed by approximately 8 percent between the extremes of these ranges. It appears that while price changes within recent ranges would have some influence on optimum nitrogen utilization and yield levels, optimal fertilization programs for corn farms would be changed only slightly with changing nitrogen prices.

Adjusting Acreages of Corn and Soybeans

Changing nitrogen prices, however, do have an impact on the proportion of cropland in corn. At recent price levels for corn and soybeans, increases of 10 cents per pound for nitrogen result in the optimum proportion of corn decreasing by 6.3 percent of the cropland acreage.

Changes in the relative price of corn and soybeans may have the greatest impact on determining acreage balance between these two crops. However, yield losses due to the timeliness factor dictate that at least part of the acreage will be devoted to each crop over a broad range of prices in the short-run.

Finally, it is apparent that optimum corn and soybean acreage in this short-run analysis could not be accurately predicted by the corn-soybean price ratio. Due to the ability of the farmer to adjust his fertilization rates at the time of planting, all inputs in the production process are not fixed. For example, as corn prices increase it is profitable to use additional nitrogen. This will increase corn production relative to soybean production at high prices and make the return to fixed resources relatively more for corn even though the corn-soybean price ratio remains constant. Thus, because of the inseparability of corn prices and fertilizer rates in the short-run, optimum proportions of corn and soybeans can be predicted only by viewing the absolute level of corn, soybean and nitrogen prices.

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