Efficient Distribution of Grain to Meet the Quality Needs of End-Users

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EXECUTIVE SUMMARY

Currently, United States grains within a grade are traded as a homogeneous commodity when, in fact, they are heterogeneous. Biotechnology will present the market with a myriad of quality special grains, placing great pressure on the current distribution system to handle differentiated grains. Forcing the current distribution system to handle quality differentiated grains may have a significant impact on producer, elevator, and processor operations and revenues. The basic purpose of this study was to examine the economic impacts of shifting from a commodity based logistics system to a quality differentiated logistics system.

An extended input characteristic model provided the framework to analyze the implications of shifting from a commodity based grain distribution system to a quality differentiated grain distribution system. The model assumed a representative firm which was an integrated producer/processor/feeder. Grain was grown and crushed by the firm which then sold the processed grain products and fed the meal and raw feed grains to slaughter animals. The firm's decision was to choose which outputs to produce, which factor inputs to employ, and which varieties of grain to produce and harvest. Results were estimated from a linear programming representation of the problem.

The first signifcant result was the fact that production of specialty grain localized around the target specialty market. For example, the farm closest to the corn wet-mill processor produced wet-mill corn and shipped it directly to the processor. This farm was capable of completely satisfying the corn demands of the wet-miller. Hence, the more distant farm did not produce wet-mill corn for shipment to the processor. From this perspective, the production of wet-mill corn for processing was centralized around the corn wet-miller.

Another striking feature was the limited role that elevators and railroads played in the model. In both solutions, little grain produced for a specific end-user moved through these channels. In the short run, for example, over 80 percent the wet-mill corn grown in the base solution was shipped by semi direct from the farm to the corn wet-miller. Moreover, farms shipped over 80 percent of their production of high-protein soybeans by semi directly to the soybean processor, bypassing the elevators and railroads. In the long run, the situation facing railroads and elevators worsens because all of the grain transported in the model moves directly from farm to market by semi, bypassing both the railroad and the elevator.

Gains to market agents from segregating quality differentiated grain vary depending on end-use and the degree of market power exerted by grain processors. In the short run, farmers have the potential to capture some of added value from quality differentiation; however, the grain processors in the model are the big short-run winners. A processor’s main competition for grain is the export market. Consequently, given the processor's inelastic demand for grain and high profit margins, the processor's grain bid yields only enough added profit per bushel to the farm to shift grain away from the export market. The remainder of the added value is captured by the processor.

In contrast, farmers can capture the entire added value of the feed variety of corn. This stems from the fact that the farmer is both the producer and end-user of the grain. Consequently, he does not have to share the value added. Moreover, in the long run, if processing plants begin to compete with each other for grain, processor market power will diminish. In this case, it is likely that the farmer will be the beneficiary of a quality differentiated system. Farmers could receive almost the entire added value per bushel.

In order to determine whether the U.S. should pursue opportunities to shift from a commodity based logistics system to a quality differentiated logistics system, the short-run model was run where the generic varieties of corn and soybeans were the only varieties available. System profits increased in both the short-run and long-run solutions when the system shifted from a commodity based to a quality differentiated logistics system. Since it is not clear how much of the increased profits will be gained by the grain producers, they must examine the short-run versus the long-run returns when determining whether or not it is in their best interest to participate in a quality differentiated logistics system. Given these results, it is plausible that a quality differentiated logistics system will evolve.

CHAPTER 1: INTRODUCTION

When defining product quality, the word *quality* is often interpreted in several ways. At times, the number of different interpretations is equal to the number of consumers and producers themselves. Webster defines quality as *a peculiar or essential character, an inherent feature, or a distinguishing attribute*. While this definition does little to define the criteria for determining quality, it does shed some light on the reasons for its many interpretations. By this definition, quality can mean different things to different individuals, depending on which attributes the individual desires. This definition of quality does not rank products as superior or inferior. Instead, it distinguishes among products in terms of the level of their attributes.

Agricultural commodities are classic examples in which quality has different interpretations to different individuals, because both output quality and output yields from different processing techniques vary with the attribute levels of the raw grain processed. For example, to a cattle feeder a high-quality corn would be high in protein, promoting maximum healthy weight gain. However, to a corn wet-miller a high-quality corn would yield a large quantity of starch. Due to the tradeoff between starch and protein, high-quality cattle feed corn would be considered low quality by the wet-miller. Consequently, grain processors attempt to procure and process grain possessing attributes consistent with the products being produced and the markets in which they will be sold.

With the large variety of end-uses for grain and grain products, it is not surprising that the grain industry has been unable to agree upon a single definition of grain quality acceptable to all grain producers, processors, and end-users. What has been established is that the quality of grain is comprised of two main components [U.S. Congress (1989)]:

1. *Soundness*. Soundness can be divided into physical and sanitary attributes. Physical attributes are those associated with the outward visible appearance of the kernel. These attributes include kernel size, shape, color, moisture content, damage, and density. Sanitary attributes refer to the cleanliness of the grain. These include foreign material, dust, broken grain, rodent excreta, insects, residues, fungal infection, and nonmillable materials. Soundness is an indicator of how well the grain will store.

2. *Intrinsic attributes*. While intrinsic attributes cannot be detected by sight, smell, or touch, they are crucial in determining the quality of the grain as they are directly related to its end-use properties. Some intrinsic attributes are protein, oil, starch, and amino acid content.

One vehicle for altering the quality of U.S. grains is varietal improvement through biotechnology. Many experts believe biotechnology has the potential to spark a second "green revolution" [Kalter and Tauer (1986)]. Biotechnology also possesses the potential to enhance the demand for commodities by producing "designer inputs" aimed at meeting the needs of end-users in specific niche markets [Hueth and Just (1987)]. In the future, genetic engineering may provide the opportunity for putting a new trait into a plant in a matter of months without sacrificing yields. Reducing the amount of time from conception to consumption will allow producers to quickly respond and take advantage of emerging market opportunities, increasing the present value of the investment. This type of "cafeteria genetics" has tremendous potential to provide specialty grains for individual end-users.

Differentiating corn and soybeans on the basis of intrinsic attributes will have an impact on current U.S. Grades and Standards. In 1916, Congress enacted the United States Grades and Standards Act (USGSA) in order to promote an emerging grain producing industry by providing a uniform and descriptive system to facilitate the long distance trading of grain. The physical uniformity of grain lots resulting from the current grades and standards has enabled the U.S. grain transportation and distribution system to become the most efficient system in the world at handling and distributing bulk commodities. Forcing the current distribution system to handle a variety of quality differentiated grains will place great stress on today's commodity oriented system. Some of the efficiencies which currently ensure lower prices for consumers and higher prices for producers via lower marketing margins may have to be sacrificed.

Problem statement

Currently, United States grains within a grade are traded as a homogeneous commodity when, in fact, they are heterogeneous. Biotechnology will present the market with a myriad of quality special grains, placing great pressure on the current distribution system to handle differentiated grains. Forcing the current distribution system to handle quality differentiated grains may have a significant impact on producer, elevator, and processor operations and revenues.

Purpose

The basic purpose of this study is to examine the economic impacts of shifting from a commodity based logistics system to a quality differentiated logistics system. This study will establish a methodology to value grains of differing qualities from a total system perspective. Much of the pioneering research concerned with valuing grains of differing quality focused primarily on the processed value of the grain. Over time, it has become abundantly clear that the logistical costs of identity preservation will play a significant role in valuing grains of different qualities. It is important to note that the goal of this study is to estimate differences in the values of grain varieties. The goal of this paper is not to estimate the values of the attributes of grain.

The second purpose of this study is to estimate the minimum premiums required for differing qualities of grain in order to return positive profits to the system. The processed value of grains of differing quality is important, but if it is not great enough to compensate for the increased logistical costs of identity preservation in the transportation and distribution system, then shifting to a quality differentiated system will not happen.

Implementing a quality differentiated system will cause grain purchase prices at elevators and processors to change to reflect the processed value of grain and the logistical costs of identity preservation. Elevators and processors who are efficient at testing and handling grains in a quality differentiated system will be at a great advantage because this efficiency allows them to offer higher grain prices to producers and earn higher profits. Those elevators and processors not well equipped to handle many qualities of grain are likely to be excluded from most quality markets. One possible alternative for those elevators and processors not capable of handling many qualities of grain may be to handle simply one or two qualities, most likely generic grains. As in the case of producers, small elevators may be forced into a similar type of specialization in one particular type of grain. This study will track the shifts in grain flows to both elevators and processors.

Elevators operating in a quality differentiated system will face constraints on marketing quality differentiated grains. To receive a premium for the qualities of grains they have segregated, elevators must sell to those markets which find value in those qualities of grain. Grains which have been identified with specific attributes are not fungible and, therefore, not as easily merchandised as those in a commodity based system. Consequently, the markets for segregated grain are essentially predetermined. This will have an impact on the modes by which the grains are shipped. This report will track shifts in the modes of transportation from elevator to processor.

The final purpose of this report is to estimate system profits, annualizing them to account for the fixed costs of identity preservation. If system profits, in this context, are positive, it is likely that a segregated distribution system will evolve.

CHAPTER 2: METHODOLOGY

An extended input characteristic model similar to that presented by Melton, Colette, and Willham (1994) provides the framework to analyze the implications of shifting from a commodity based grain distribution system to a quality differentiated grain distribution system. The model assumes a representative firm which is an integrated producer/processor/feeder. The grain is grown and crushed by the firm which then sells the processed grain products and then feeds the meal and raw feed grains to slaughter animals [Just and Hueth (1979)]. The firm is a profit maximizer of a multi-output, multiple stage production process including:

1. producing grain
2. processing grain into meal, oil, gluten feed, ethanol, etc.
3. feeding raw grain and processed grain products to slaughter-animals

The firm's decision is to choose which outputs to produce, which factor inputs to employ, and which varieties of grain to produce and harvest.

The extended ICM problem was formulated as a linear programming problem from which the empirical results will be derived. Assume the integrated representative firm selects grain varieties from among a finite number of commercially available varieties in order to maximize the net returns to the given resources (land, capital, labor, equipment, etc.) at fixed prices. A linear programming representation of this problem (similar to a blending ICM) can be stated as the following:

$$Max\ Z = \sum_{m=1}^{M} c_m N_m + \sum_{g=1}^{G} c_g N_g + \sum_{l=1}^{L} c_l N_l + \sum_{t=1}^{T} c_t N_t + \sum_{p=1}^{P} c_p N_p \qquad \textbf{(1)}$$

N

subject to:

$$\sum_{j=1}^{M+G+T+L+P} a_{ij}N_j \leq b_i \qquad i = 1,2,...,I \qquad \textbf{(3)}$$

$$N_j \geq 0 \qquad \forall \qquad 1 \leq j \leq M+G+L+T+P \qquad \textbf{(2)}$$

where:

N = firm activity,

c = net return from activity,

m = product marketing activities of the firm,

g = grain production activities of the firm,

l = livestock production activities of the firm,

t = logistics activities of the firm,

p = grain processing activities of the firm,

b_i = total amount of the ith resource available to the firm, and

a_{ij} = total amount of the ith resource required per unit of the jth activity.

Denote Z^0 as the optimal objective function value arising form selection of an optimal variety. The relative economic value of each variety, N_g, can be derived for the fixed resource base as the following:

$$\frac{\Delta Z^o}{\Delta N_g} = \sum_j c_j \frac{\Delta N_j}{\Delta N_g} = z_g - c_g \qquad \textbf{(4)}$$

Equation 4 is equal to the shadow price of an acre of production of the gth variety (activity) at a zero level in the optimal solution, where $z_h=\Sigma_i y_i a_{ij}$ = the indirect or opportunity cost of the hth activity in terms of its resource requirement and y_i = shadow price or imputed value of the ith resource. At Z^0 the condition $\Sigma_j(c_j - z_j)N_j = 0$ holds. Therefore, for $N_j>0$, $c_j - z_j = 0$, while for any other $N_j = 0$, $c_j - z_j < 0$ [Dorfman, Samuelson, and Solow(1958)]. Subtracting the shadow price from the value of the optimal grain variety yields the value of the non-optimal variety of grain. In other words, $(\Delta Z^o/\Delta N_g)$ divided by the optimal variety's yield is the maximum per bushel premium paid for the optimal variety of grain above the per bushel price of the gth variety of grain.

CHAPTER 3: DATA

The study area consists of two regions in Iowa. The first region is Marshall County in eastern Iowa. Marshall County is dominated by small country elevators nested within trucking distance of several Iowa grain processors. The majority of the grain within Marshall County is transported by truck to these processors. The remainder is shipped to New Orleans, Louisiana, for export via the Mississippi River. Finally, many of these small elevators have become dated in terms of their technology and size.

In contrast, the second study region consists of Webster and Calhoun counties in western Iowa. These counties are essentially dominated by two large cooperatives. These cooperatives are predominantly rail shippers since they are located long distances from processor and barge markets. Moreover, the facilities comprising these two cooperatives are more current in terms of their technology (computerized) and size. These two study regions were chosen because they are typical of the market structures present in the state of Iowa. Consequently, the impacts of shifting from a commodity based distribution system to a quality differentiated distribution system should be accurately reflected by the results from these two study areas.

Farm-level data

One representative farm was constructed in each study region. Each farm had the opportunity to produce three varieties of corn, three varieties of soybeans, and livestock. The three varieties of corn have been labeled as wet-mill, feed, and generic, according to the market they target. Table 1 presents the attributes intrinsic to each variety of corn. Since wet-mill corn targets the corn wet-milling industry as a consumer, its starch content is greater than the other two—3.0 percent more starch than generic corn and 4.5

percent more than the feed corn. Similarly, feed corn targets the livestock market, which demands a corn variety high in protein—3.0 percent more protein than generic corn and 4 percent more than wet-mill corn. Generic corn is more middle-of-the-road in its attribute levels, and it represents an average bushel of corn in today's undifferentiated market.

TABLE 1 Corn Attribute Levels Based on 12 Percent Moisture (Percent)

	Corn variety		
Attribute	Wet-mill	Feed	Generic
Crude protein	7.0	11.0	8.0
Crude oil	3.6	3.6	3.6
Starch	63.0	58.5	60.0
Lysine	0.3	0.3	0.3
Methionine	0.2	0.2	0.2

Similarly, each farm has a choice of producing three varieties of soybeans: high-protein, high-oil, and generic. Table 2 lists the attribute levels for the three varieties of soybeans [Brumm and Hurburgh (1990)]. The high-protein variety has a crude protein content of 38 percent and a crude oil content of 16.6 percent. The high-oil variety has a crude protein content of only 31.6 percent and a crude oil content of 20.1 percent. Again, the generic variety of soybeans reflects more average levels of protein and oil and represents a typical soybean produced in today's undifferentiated market. This variety has a crude protein content of 35.5 percent and a crude oil content of 18.2 percent.

TABLE 2 Soybean Attribute Levels Based on 13 Percent Moisture (Percent)

	Soybean variety		
Attribute	High-protein	High-oil	Generic
Crude protein	38.0	31.6	35.5

Crude oil	16.6	20.1	18.2

Data on variety-specific per acre production levels and costs were not available. Industry has suggested that both per acre yields and costs are likely to vary by variety; however, no quantitative information could be provided. Consequently, per acre production levels and costs were assumed constant across varieties within a crop.

Crop production per acre for both farms was assumed to equal average county levels. Yields in Webster and Calhoun counties were simply averaged and assigned to the representative farm in that region. Table 3 reports per acre corn and soybean production for both study areas for the time period 1990–1993 [Iowa Crop and Livestock Reporting Service (1991–1994)]. The years 1990 and 1991 are typical production figures for Iowa; however, the years 1992 and 1993 are not. In 1992, Iowa experienced a superb growing year resulting in a record breaking crop. The year 1993 was quite the opposite, as Iowa's production was stifled as a result severe flooding. On average, these two years nullify each other.

TABLE 3 Iowa and County Corn and Soybean Yields (Bushels per Acre)

Commodity	County	1990	1991	1992	1993	Average
Corn	Calhoun	146	136	170	83	134
	Marshall	130	121	152	86	122
	Webster	143	130	163	83	130
	Iowa	126	117	147	80	118
Soybeans	Calhoun	44	43	47	28	41
	Marshall	45	43	47	35	43

	Webster	43	42	46	26	39
	Iowa	42	41	44	30	39

The average yields per acre for corn and soybeans in Marshall County for this time period were 122 bushels and 43 bushels, respectively. These yields per acre were assigned to the representative farm in Marshall County. Webster and Calhoun counties saw corn yields average 130 and 134 bushels per acre, respectively. Soybean yields per acre over this same time period averaged 39 bushels in Webster County and 41 bushels in Calhoun County. The representative farm in this study region was assigned an average corn yield of 132 bushels per acre and an average soybean yield of 40 bushels per acre.

The cultivation practices of each farm were determined from examining the average number of acres in production for the period 1990–1993, shown in Table 4 [Iowa Crop and Livestock Reporting Service (1991–1995)]. In Table 4, corn acres in Marshall County range from 138,000 to 156,000. Average corn acres in production over the time period are approximately 150,000. Soybean acres in Marshall County range from 80,000 to 89,000. Average soybean acres in production over the time period were approximately 84,000. Based on the averages, corn acres are 1.8 times greater than soybean acres. This implied using a corn/corn/soybean rotation on the Marshall County farm.

TABLE 4 Iowa and County Corn and Soybean Acres in Production (Thousands of Acres)

Commodity	County	1990	1991	1992	1993	Average
Corn	Calhoun	161	151	166	150	157
	Marshall	156	148	156	138	150

	Webster	182	170	187	172	178
	Iowa	12,800	12,500	13,200	12,000	12,625
Soybeans	Calhoun	150	171	149	159	157
	Marshall	80	87	82	89	84
	Webster	169	187	170	181	177
	Iowa	8,000	8,700	8,150	8,600	8,363

In Calhoun County, corn acres in production ranged from 166,000 in 1992 to 150,000 in 1993. The average number of acres in production were approximately 157,000. Soybean acres in Calhoun County ranged from 150,000 in 1990 to 149,000 in 1992. The average number of soybean acres in production over the same time period were 157,000. Consequently, the ratio of corn acres to soybean acres is approximately one-to-one in Calhoun County. The results for Webster County are analogous to Calhoun County, only the magnitudes differ. This one-to-one ratio in Webster and Calhoun counties implies a corn/soybean rotation schedule for this region.

No county-level data on the costs of production were available. Consequently, State of Iowa averages had to be used. The costs of producing an acre of corn or soybeans in the state of Iowa are shown in Table 5 [Duffy and Judd (1994)]. It was assumed the higher costs associated with producing corn following corn were due to maintaining yields. Thus, for the representative farm in Marshall County, for every acre of corn produced, it was assumed that one-half acre was following corn and the other was following soybeans, leading to an average cost of production of $207.67 per acre. The cost of producing corn on the representative farm in Webster and Calhoun counties was $197.92 per acre. The cost of producing soybeans was assumed to be identical across regions and was equal to $142.83 per acre.

Livestock production

In order to capture grain feed values, grain producers were also assumed to produce livestock. These two markets were simply the farmer feeding corn to livestock right out of the fields. To simplify the LP model, livestock classes produced within each livestock market were aggregated into grain consuming units. The grain consuming units in each feed market were constructed from five livestock classes. Livestock classes included beef-fed, pork-sows, pork-fed, lamb-fed, and dairy cattle. These five classes were chosen because they account for over 95 percent of the grain fed in Iowa [McVey et al. (1990)].

TABLE 5 Iowa Corn and Soybean Production Costs per Acre (Dollars per Acre)

	Corn following soybeans				
Cost Item	1990	1991	1992	1993	Average
Machinery	$ 76.85	$ 91.12	$ 70.27	$ 74.58	$ 78.21
Materials	104.85	96.50	99.40	106.07	101.71
Labor	18.00	18.00	18.00	18.00	18.00
Total	199.70	205.62	187.67	198.65	197.92
	Corn following corn				
Machinery	$ 81.65	$ 96.09	$ 72.78	$ 76.14	$ 81.67
Materials	119.70	109.93	113.37	118.36	115.34
Labor	20.40	20.40	20.40	20.40	20.40
Total	221.75	226.42	206.55	214.90	217.41
	Soybeans following corn				
Machinery	$ 52.68	$ 61.01	$ 45.46	$ 46.29	$ 51.36
Materials	74.15	74.49	74.95	79.87	75.87
Labor	15.60	15.60	15.60	15.60	15.60

Total	142.43	151.10	136.01	141.76	142.83

Nutrient requirements for the three different grain consuming units were estimated by first multiplying the average daily nutrient requirements for each livestock class by the number of head in the livestock class in each market. This step yields the average daily nutrient requirements for the entire livestock class within each livestock feed market. Summing across livestock classes yields the total daily nutrient requirements for the entire market. Dividing the total daily nutrient requirements by the total number of grain consuming units in each market and multiplying by 365 days yields the total nutrient requirement for one grain consuming unit. The total number of grain consuming units in each market is simply the sum of the number of head in each livestock class. County livestock levels were scaled to the farm level by the relative share of farm acres to county acres in production. The farm in Marshall County had a livestock capacity of 1,159 grain consuming units and the farm in Webster-Calhoun counties had a livestock capacity of 668 grain consuming units. The annual nutrient requirements for one grain consuming unit are presented in Table 6 [National Research Council, (1985,1986, 1988)]. A complete explanation of how the nutrient requirements for each livestock class were estimated are presented in Appendix A.

TABLE 6 Annual Nutrient Requirements for one Grain Consuming Unit, by Farm

	Farm	
Nutrient	Marshall	Webster-Calhoun
Dry matter (lbs)	1,450.61	1,346.93
Metabolizable energy (Mcal)	1,890.32	1,779.41
Protein (lbs)	172.29	162.40

Amino acids		
Lysine (lbs)	6.64	6.77
Methionine (lbs)	3.66	3.73

In satisfying livestock nutrient requirements, each livestock market was allowed to formulate feed rations from the three varieties of corn and processed feed supplements. Soybeans were not fed directly to livestock because the trypsin inhibitor in soybeans can be toxic to swine. Table 7 indicates the metabolizable energy provided to livestock by each variety of corn [National Research Council (1985, 1986 ,1988)]. Differences across livestock markets accrue to differences in the livestock shares composing the grain consuming unit. In all three livestock markets, the wet-mill variety of corn provides the most metabolizable energy, and the feed variety of corn provides the least. What makes the feed corn variety valuable to livestock feeders, however, is the amount of protein available per bushel. Livestock producers face the trade off between the amount of protein and the amount of metabolizable energy provided when deciding which corn variety to feed.

TABLE 7 Metabolizable Energy Provided by Each Variety of Corn, by Farm, on an As Fed Basis (Mcal/lb)

	Corn variety		
Livestock market	Wet-mill	Feed	Generic
Marshall	1.585	1.506	1.532
Webster-Calhoun	1.590	1.510	1.537

Four processed outputs were included as possible feed supplements: corn gluten feed, corn gluten meal, and soybean meal—44 and 48 percent protein.

Corn gluten feed and meal are by-products produced in the corn wet-milling process. In the model, the glutens are produced from each of the three varieties of corn. In all likelihood, the nutrient content of the glutens varies according to the corn from which it was produced. However, since no data are available to quantify the differences, the corn gluten nutrients were assumed to be constant across corn varieties. The two soybean meals are outputs from soybean processing. All are high-quality feed supplements. The final feed supplement allowed in the ration formulation was corn silage. Corn silage was assumed to be produced on farm from any of the three corn varieties. As with the corn glutens, the nutrient content of the silage produced is likely to vary with the variety of corn planted. Again, since no data were available to quantify the differences, the nutrients provided by corn silage were assumed across corn varieties. Table 8 presents the attribute levels for all of the feed products fed to livestock [National Research Council (1985, 1986, 1988)].

TABLE 8 Feed Product Attribute Levels, on an As Fed Basis

Attribute	Corn gluten feed	Corn gluten meal	Soybean meal (44%)	Soybean meal (48%)	Silage
Moisture percent	9.0	9.0	10.0	10.0	67.0
Crude protein percent	23.3	42.1	44.0	48.5	12.1
Crude oil percent	2.7	2.3	1.1	0.9	4.6
Lysine percent	0.6	0.8	2.9	3.1	0.6
Methionine percent	0.4	1.1	0.5	0.7	0.7
Metabolizable energy (Mcal/lb)					
Marshall	1.421	1.883	1.412	1.488	0.034
Webster-Calhoun	1.424	1.895	1.416	1.491	0.026

The cost of feeding the different feed ingredients varied by type of ingredient. Discussions with local feed mills estimated the cost of feeding the three varieties of corn to be $12.00 per ton. This cost included $3.00 per ton to blend the feed and $9.00 per ton to grind and roll the corn. The processed feed supplements were only assessed the $3.00 per ton blending fee for feeding costs. The cost to feed silage was estimated to be $15.00 per ton. Silage incurred the largest costs because it is a bulky ingredient requiring large machinery and equipment to distribute it.

Again, no data regarding the non-feed costs of producing livestock were available at the county level. As before, State of Iowa data were substituted. Table 9 shows the average non-feed cost of production per head for each class of livestock for the state of Iowa [Lawrence et al. (1994)]. The non-feed costs of production ranged from $20.81 per head for pork-fed to $1,252.66 per head for dairy cattle. The costs listed in Table 9 were converted to a cost per grain consuming unit by weighting the cost of production for each livestock class by its share in production and summing the results. The cost of producing one grain consuming unit in Marshall County was $70.54. In Webster-Calhoun counties the cost was $60.41 per grain consuming unit.

TABLE 9 Non-Feed Production Costs for Selected Livestock Classes (Dollars per Head)

	Livestock class				
Cost Item	Beef-fed	Pork-sows	Pork-fed	Lamb-fed	Dairy
Feeder costs	$ 429.00			$ 45.50	
Interest (10%)	25.50			1.25	
Veterinary, health	10.00	$ 20.00	$ 1.50	5.00	$ 45.00

Fuel, repairs, utilities	11.00	30.00	2.00	1.00	90.00
Marketing	14.00	20.00	2.00	2.00	66.00
Labor ($7.00/hour)	21.00	70.00	5.25	10.50	420.00
Breeding fees					20.00
Bedding					70.00
Interest (10%)	6.54	5.48	0.83	0.30	270.83
Machinery, equipment, housing	19.00	66.49	9.23	3.00	270.83
Boar depreciation		10.00			
Interest, insurance		11.18			138.60
Total	536.04	221.97	20.81	68.55	1,252.66

Livestock prices

Prices received for livestock were constructed similar to livestock production costs. Table 10 presents Iowa [Wisner et al. (1995)] livestock prices received over the period from 1991 to 1994. Income per animal was calculated by multiplying each animal's average production by its corresponding commodity price. The annual production per animal was 1,100 pounds for beef-fed, 152 pounds for pork-sows, 250 pounds for pork-fed, 110 pounds for lamb-fed, and 12,000 pounds of milk for dairy [Lawrence et al. (1994)]. The income from one grain consuming unit

TABLE 10 Average Annual Commodity Prices 1991–1994 (Dollars per Hundred Weight)

	Livestock class

Market	Year	Beef-fed	Pork-sows	Pork-fed	Lamb-fed	Dairy
Iowa	1991	$ 72.30	$ 41.63	$ 50.50	$ 51.40	$ 11.90
	1992	69.60	34.00	42.50	59.50	13.00
	1993	71.60	36.99	46.10	63.90	12.80
	1994	65.50	31.87	40.80	68.00	12.56
	Average	69.75	36.12	44.98	60.70	12.57

was calculated as the weighted average of income per animal where the weights were the shares of each livestock class in production. The income received from one grain consuming unit in Marshall County was $156.26 and in Webster and Calhoun counties was $143.14.

Elevator data

In the model, grain producers were able to ship grain to four local elevators: Marshalltown and Liscomb in Marshall County and Rinard and Farnhamville in Webster and Calhoun counties. The elevators in Marshall County are small independent elevators that predominantly ship their grain to market by truck. The elevators in Webster and Calhoun counties are typically branches of larger cooperatives. Farnhamville has large unit-train shipping capability, while Rinard is a small truck elevator. Table 11 presents the four study elevators along with their capacities and rail capabilities.

TABLE 11 Elevator Locations, Capacities (Bushels), and Rail Capability

County	Location	Capacity	Rail
Marshall	Marshalltown	820,000	no

	Liscomb	1,000,000	yes
Webster-Calhoun	Rinard	881,000	no
	Farnhamville	6,884,000	yes

Data regarding elevator costs, on a per bushel basis, are considered proprietary information and difficult to acquire. Hence, elevator cost data had to be obtained from two alternative secondary data sources. First, data regarding the cost of handling and merchandising grain in today's market were extracted from Chase, Helgeson, and Shaffer (1983). In their report, Chase et al. surveyed 463 elevators in South Dakota on their cost of handling grain. They provided average total costs, in cents per bushel, stratified by total quantity of bushels handled by the elevator. The four study elevators were categorized to fit the Chase et al. data based on the average annual grain passing through each elevator. These data, however, do not address the incremental costs of segregating intrinsically different grains.

The second set of data were used to estimate the incremental costs per bushel of segregating and handling quality grains. However, a methodology for estimating the incremental costs of segregating and handling grain was developed [Hurburgh et al. (1994)]. This methodology is presented in Appendix B. Using data from an unpublished survey, Hurburgh, et al. (1994) estimated the incremental segregation costs per bushel. Table 12 presents the grain handling costs per bushel for the four elevators in today's undifferentiated market, incremental costs for handling grain in a differentiated market, and the total cost of handling grain in a differentiated market.

TABLE 12 Elevator Handling Costs in an Undifferentiated Market, Incremental and Total Handling Costs for a Differentiated Market (Cents per Bushel)

County	City	Generic handling cost	Differentiated handling costs	
			Incremental	Total
Marshall	Marshalltown	12.2	3.09	15.29
	Liscomb	10.9	3.13	14.03
Webster-Calhoun	Rinard	12.2	2.96	15.16
	Farnhamville	10.9	1.42	12.32

Grain processing data

Corn processing

Corn wet-milling is a complex industrial process. The primary products from this process are corn starch and starch derived chemicals. Starch can be processed further to improve its food uses and industrial products. Starch can be chemically modified to resist changes when stored, treated with natural proteins to produce high fructose corn syrups found in soft drinks, or fermented to produce alcohol. In theory, starch can be converted into a wide assortment of industrial chemicals now produced from petroleum sources.

The corn wet-milling process also produces several valuable by-products. A major by-product is corn oil. Processed further, corn oil can be converted into various salad oils and similar products. Wet-milling also produces corn gluten feed and corn gluten meal that are used as high-quality animal feeds. The wet-milling industry is the largest non-feed user of corn, using approximately one billion bushels annually [Huber et al. (1995)].

For the model, a representative corn processing plant was created to account for the processed value of the corn, and it was assumed to be located in Cedar Rapids. Currently, Cedar Rapids has three corn processors in operation. Since the cost per bushel to process corn are directly related to the capacity of the plant, the capacity of the processor created was assumed to equal the average plant capacity in the state of Iowa. Table 13 provides a list of wet-mill processors in Iowa, their locations, and average daily throughput [Iowa Corn Growers Association (1995) and Zdrojewski (1995)].

TABLE 13 Plant Locations and Average Daily Throughput of Iowa Corn Wet-Millers in 1992 (Bushels)

Company	Location	Average daily throughput
Archer Daniels Midland	Cedar Rapids	335,000
Archer Daniels Midland	Clinton	410,000
Cargill	Eddyville	225,000
Cargill	Cedar Rapids	75,000
Grain Processing Corp.	Muscatine	140,000
Roquette American	Keokuk	120,000
Penford Products Co.	Cedar Rapids	55,000
Average		194,286

Plant capacities range from 55,000 bushels per day at Penford Products in Cedar Rapids to 410,000 bushels per day at Archer Daniels Midland (ADM) in Clinton. The average plant throughput in the state of Iowa was 194,268 bushels per day. In the model, the representative plant in Cedar Rapids was assumed to process 200,000 bushels per day.

Table 14 is a list of the products produced by the wet-mill processors at each plant in Iowa [Huber et al. (1995)]. From Table 14, it is clear that plants differ in the products produced. At least four of the eight processors listed produced starch, glucose, high fructose corn syrup (HFCS), and fuel ethanol. For modeling purposes, the representative plant in Cedar Rapids was also assumed to have the capabilities to produce starch glucose, HFCS, and ethanol. No one processor in Table 14 produces all four products, but the combination of the three processors in Cedar Rapids do produce all four.

TABLE 14 Iowa Wet-Millers and Selected Products

	Products produced by wet-milling facilities				
Processing firm	Basic and modified starches	Glucose corn syrup	Crystalline dextrose	HFCS	Fuel ethanol
ADM (Cedar Rapids)		X		X	X
ADM (Clinton)	X		X	X	X
Cargill (Eddyville)				X	
Cargill (Cedar Rapids)	X	X			
Grain Processing Corp.	X				X
Roquette American	X	X		X	X
Penford Products Co.	X	X			
Number of products	5	4	1	4	4

The average output of products from a bushel of corn varies by processor due to differences in processing techniques and goals. Table 15 presents the average product yields per bushel from processing corn [Huber et al. (1995)]. In the wet-milling process, the first five products are always produced. However, the process does not always stop there. Starch can be further converted into glucose, which in turn can be converted into HFCS or fermented to produce ethanol.

TABLE 15 Average Product Yields from Processing one Bushel of Corn

Product	Pounds	Percent
Starch*	31.5	56.3
Gluten feed	13.5	24.1
Gluten meal	2.6	4.6
Crude oil	1.6	2.9
Water	6.8	12.1
Total	56.0	100.0
* Or		
Sweetener	33.3 dry	
Ethanol	2.6 gallons	

The processing yields for each variety of corn are presented in Table 16. It was assumed that 98 percent of the starch could currently be recovered by the wet-mill process, which is in line with the yields reported by the pilot wet-mill plant established at Iowa State University [Fox (1995)]. Fox speculates that current Iowa wet-millers experience similar starch recovery rates. Oil recovery was assumed to be 100 percent. The gluten product yields from the wet-mill process were estimated by calculating the shares of the glutens in the corn remaining after the starch and oil extraction from Huber et al. (1995). These shares were then applied to the three corn varieties in the model. Table 16 presents the output yields from this process.

TABLE 16 Wet-Mill Product Yields, by Variety

		Corn variety		
Product	Units	Wet-mill	Feed	Generic
Starch*	Pounds	34.57	32.10	32.93
Gluten feed	Pounds	10.66	12.73	12.04
Gluten meal	Pounds	2.03	2.43	2.30
Crude oil	Pounds	2.02	2.02	2.02
* Or				
Glucose	Pounds dry	36.55	33.93	34.81
HFCS 55	Pounds dry	36.55	33.93	34.81
Ethanol	Gallons	2.85	2.65	2.72

The per bushel production of glucose was estimated using the assumption that one pound of starch can be converted into 1.057 pounds of dry glucose [Huber et al. (1995)]. Per bushel production of HFCS 55 and ethanol were estimated, assuming that one dry pound of glucose can be converted into one dry pound of HFCS or 0.078 gallons of ethanol [Huber et al. (1995)].

Given a plant capacity of 200,000 bushels per day, cost data regarding the production of starch and glucose were provided by a computerized wet-mill simulation model developed at the Natural Resources Energy Lab (NREL) [Landucci (1995)]. This simulation provided data on the cost of processing corn into starch and the cost of converting the corn starch into corn glucose. Using the Huber et al. data, the glucose production data was converted to dollars per pound of starch, assuming 1:1057 conversion rate of starch to glucose. Table 17 shows the cost of producing starch, glucose, HFCS 55, and ethanol. For a detailed explanation of the processing cost data, see Appendix C.

TABLE 17 Wet-Mill Production Costs for a 200,000 BPD Plant

Output	Cost in cents
Starch	¢48.36 / bu Corn
Glucose	1.23 / lb Starch
HFCS 55%	5.79 / lb Glucose
Ethanol	13.90 / Glucose

Corn glucose is often converted into the popular sweetener, HFCS 55. Descriptive data on the conversion of glucose to HFCS 55 were not available; however, a variable cost estimate was available [Vuilleumier (1985)]. The total variable cost of producing fructose from a bushel of corn was 6.5 cents per pound (dry). Using the NREL data provided on starch and glucose production, fixed costs range from 33–37 percent of total costs. Assuming fixed costs represent 33 percent of the total cost of producing HFCS 55, the total cost of producing one pound of HFCS 55 is 9.7 cents per pound of glucose. This 9.7 cents, however, includes the starch and glucose production phases also. Subtracting the costs of starch and glucose production results in a cost of 5.79 cents per pound of glucose to convert glucose into HFCS 55, assuming a 1:1 conversion factor of glucose to HFCS.

Ethanol can also be made from the fermentation of corn glucose. One pound of glucose can be converted into 0.0781 gallons of ethanol. It was assumed that ethanol was produced in a batch fermentation process with no cell recycling [Busche (1995)]. The total cost of producing ethanol in a 60 million gallon per year facility was $1.78 per gallon. Using the glucose-ethanol conversion factor, this translates into 13.9 cents per pound of glucose.

Soybean processing

Soybean solvent extraction, the component separation of oil and protein-carbohydrate-fiber (meal), is the most common method for processing soybeans into soybean oil and soybean meal in the United States [Brumm and Hurburgh (1990)]. The end-product yields from this technique depend heavily upon the protein and oil content of the raw soybeans. Solvent extraction is a three- step process [Brumm and Hurburgh (1990)]. In step one, soybeans are cleaned, dried, and cracked into fourths and eighths. Hulls released during cracking are removed. The remaining meats are conditioned to an appropriate temperature and moisture content for flaking. In step two, oil is extracted from the flakes with an organic solvent and reclaimed to yield crude soybean oil. The defatted flakes are then desolventized and toasted in preparation for the final step. In the final step, the flakes are ground and screened to make soybean meal. Previously separated hulls are usually added to the meal to lower the protein content to product specifications. Remaining hulls can be traded or saved for future use.

There are three soybean processing firms with plants in Iowa. These three firms own and operate 10 processing plants in nine different locations [Iowa Soybean Association (1995)]. Table 18 lists the three firms, plant locations, and plant capacity at which they operate, assuming they operate at 100 percent efficiency. The plant capacities are estimates based on information that could be gleaned from industry. The total capacity of these 10 plants is approximately 750,000 bushels per day (Industry Sources). By dividing the state's total capacity by the number of operating plants, the average operating capacity per plant in the state is roughly 68,000 bushels per day (bpd). For the model, a plant was constructed in Iowa Falls with a daily crush equal to the average 68,000 bpd.

TABLE 18 Iowa Soybean Processing Firms, Crushing Capacities, and Plant Locations

Processing firm	Plant location	Average daily crush (in bushels)
AGP	Eagle Grove	100,000
	Manning	40,000
	Mason City	60,000
	Sergeant Bluff	85,000
	Sheldon	40,000
Cargill	Cedar Rapids (East)	80,000
	Cedar Rapids (West)	35,000
	Des Moines	55,000
	Iowa Falls	60,000
	Sioux City	80,000
Archer Daniels Midland	Des Moines	115,000
Average		68,182

The output per bushel for each of the three soybean varieties is shown in Table 19 [Brumm and Hurburgh (1990)]. From Table 19, notice how the meal production from the high-oil variety is considerably lower than the other two varieties. This stems from the fact that there is a 2:1 tradeoff for protein in terms of oil [Soybean Trait Modification Task Force (1990)]. In other words, an increase of one percentage point in the oil content of the soybean results in a two percentage point decrease in the protein content of the soybean. It is this protein decrease that translates into lower soybean meal yields. The quantity of soybean meal with 48 percent protein was estimated by removing the hulls from the meal, which are approximately 10 percent of the bulk.

TABLE 19 Soybean Processing Outputs, by Soybean Variety (Pounds)

	Soybean variety		
Livestock market	High-protein	High-oil	Generic
Soybean meal 44%*	53.10	42.00	48.90
Soybean oil	9.70	11.80	10.60
* Or			
Soybean meal 48%	48.27	38.18	44.45

Variable soybean processing costs for a 68,000 bpd facility were assumed to be 33 cents per bushel [Fiala (1995)]. Indirect and fixed costs added another nine cents per bushel [Fiala (1995)]. Hence total processing costs were assumed to be 42 cents per bushel.

Prices of processed grain products

Table 20 presents a list of the processed grain output prices used in the model. Prices for the corn glutens and corn starch were gathered from various years of the USDA's *Feed Situations and Outlook Yearbook*. Processed soybean output prices were gathered from various years of the USDA's *Oil Crops Yearbook*. Corn glucose and HFCS 55 prices were gathered from various years of the USDA's *Sugar and Sweetener Situation Outlook Report.* Ethanol prices were attained from personal communication with the Iowa Corn Growers Association. Only the 1993 and 1994 fiscal years were available for ethanol prices. The average prices over the four-year period were used as parameters in the model.

TABLE 20 Processed Grain Output Prices Reported, by Fiscal Year

Product	Units	90/91	91/92	92/93	93/94	Average
Corn oil	Cents/pound	27.50	25.82	20.90	26.38	25.15
Corn gluten meal	Dollars/ton	237.68	265.79	284.60	286.61	268.67
Corn gluten feed	Dollars/ton	97.94	101.49	95.95	88.62	96.00
Corn starch	Dollars/hundredweight	11.02	11.03	10.70	12.61	11.34
Corn glucose	Cents/pound	14.53	16.48	12.50	15.11	14.66
HFCS 55%	Cents/pound	22.50	23.75	20.60	22.87	22.43
Ethanol	Dollars/gallon	-	-	1.13	1.16	1.15
Soybean oil	Cents/pound	21.00	19.10	21.40	27.09	22.15
Soybean meal 44%	Dollars/ton	168.80	177.70	180.80	181.82	177.23
Soybean meal 48%	Dollars/ton	181.40	189.20	193.75	192.86	189.30

Export market

For both Marshall County and Webster-Calhoun counties, the export market was assumed to not differentiate grain based on quality. This assumption was necessary to prevent a myriad of possible alternative activities due to which importers test, which prefer which quality, and which transportation route is most optimal. While these activities are well within the realm of relevant quality issues, they are beyond the scope of this study.

The export market was introduced into the model by creating a barge terminal at East Clinton, Illinois. This facility was assumed to be capable of handling all grain shipped from elevators in Marshall County and Webster-Calhoun counties. This facility was assumed to operate the entire year, except when the upper Mississippi River is frozen. The upper Mississippi River was assumed closed to barge traffic at East Clinton from the third week in December to the third week in March. Corn and soybean bids for the facility were an average of the f.o.b. delivered bids at East Clinton over the period 1991–1994, excluding periods when the river is frozen. The average cash closing bid was $2.38 for corn and $5.94 for soybeans.

Transportation costs

Both farms, one in Marshall County and one in Webster and Calhoun counties, were allowed to ship grain to the four elevators in the model. Table 21 shows the one-way miles from each farm to each of the local elevators. The distance from each farm to two elevators in the same county were assumed to be equal across counties. When farmers transport grain from farm to elevator without rail capabilities, the grain travels an average of 4.5 miles one-way. When farmers transport grain to elevators with rail capabilities the grain must travel an average of 11 miles one-way [Baumel et al. (1996)]. Consequently, the farms were located accordingly.

TABLE 21 One-Way Miles from Farm to Elevator

Farm location	Marshalltown	Liscomb	Rinard	Farnhamville
Marshall	4.5	11.0	109.5	101.5
Webster-Calhoun	108.0	117.5	4.5	11.0

To simplify the model, farms were limited to two types of vehicles for transporting grain from farm to market: (1) a tractor pulling two 300-bushel wagons, or (2) a semi tractor-trailer capable of hauling 1,000 bushels. The transport cost per mile for farms was assumed to be equal to the commercial transport rates charged by each type of vehicle. For semi tractor-trailers, a commercial rate of $1.00 per mile was assumed (Industry Sources) and for tractor-wagon, the cost per mile to transport grain was assumed to be $1.20 [Edwards and Vontalge (1995)]. It is clear from the commercial transport rates that it is more cost effective to ship grain by semi tractor-trailer rather than by tractor-wagon. Table 22 presents the total round trip transport cost for shipping grain from farm to elevator by tractor with two wagons and by semi.

Farms were also allowed to bypass the local elevators and ship their grain directly to the processor. Processors, however, were assumed to only receive grain delivered by rail or semi tractor-trailer. Consequently, farmers could only ship to the processor using semi tractor-trailers. Table 23 presents the one-way miles from each farm to each processor.

TABLE 22 Farm-to-Elevator Grain Transport Costs, by Vehicle Type

Vehicle	County	Marshalltown	Liscomb	Rinard	Farnhamvil
Tractor-wagons	Marshall	$ 11.00	$ 26.00	$ 263.00	$ 243.00
	Webster-Calhoun	259.00	282.00	11.00	26.00
Semi	Marshall	9.00	22.00	219.00	203.00
	Webster-Calhoun	216.00	235.00	9.00	22.00

TABLE 23 Distance from Farm to Market (One-Way Miles)

Farm location	Cedar Rapids	Iowa Falls
Marshall	68.0	61.5

Webster-Calhoun	166.5	69.5

Both processors are located within close proximity to the farm in Marshall County—68.0 miles to the corn wet-miller in Cedar Rapids and 61.5 miles to soybean processor in Iowa Falls. The soybean processor in Iowa Falls is located between both farms, while the corn wet-miller in Cedar Rapids is east of Marshalltown, which is east of Webster and Calhoun counties. Consequently, the farm in Webster-Calhoun counties must travel farther to the corn wet-miller than to the soybean processor—166.5 miles one-way compared to 69.5 miles one-way.

Table 24 presents the round-trip transport charge per semi from farm to processor. The cost to transport grain from the Marshall County farm was $136.00 to Cedar Rapids and $123.00 to Iowa Falls. Similarly, the cost to ship grain from the farm in Webster-Calhoun counties was $333.00 to Cedar Rapids and $139.00 to Iowa Falls. Marshall County has a considerable competitive advantage over Webster-Calhoun counties when shipping corn to the wet-miller in Cedar Rapids. The Marshall County advantage is significantly less in the soybean market.

TABLE 24 Semi Grain Transport Costs from Farm to Market

Farm location	Cedar Rapids	Iowa Falls
Marshall	$136.00	$123.00
Webster-Calhoun	333.00	139.00

All four elevators in the model were allowed to ship corn and soybeans to the processors and to the Mississippi River for export. The elevators in Marshalltown and Rinard shipped grain via semi only, since they do not possess rail capabilities. The elevators in Liscomb and Farnhamville were allowed to ship grain to markets either by semi or rail. Table 25 presents the one-way miles from each elevator location to each market.

TABLE 25 One-Way Miles from Elevator to Market

Origin	Cedar Rapids	East Clinton	Iowa Falls
Marshalltown	68	151	54
Liscomb	83	166	49
Rinard	165	251	70
Farnhamville	157	243	70

Using the commercial transport rate of $1.00 per mile for a semi load of grain, Table 26 presents the grain transport rates from elevator to each of the Iowa markets. The rail rates are in dollars per car (Industry Sources). A single rail car can haul approximately 3,500 bushels. The rail rate from Liscomb and Farnhamville to the corn processor in Cedar Rapids were not included in Table 26, because this rate is bid as East Clinton (Industry Sources). In other words, the rate per carload quoted to Cedar Rapids is quoted as if the carload were going to East Clinton.

TABLE 26 Commercial Transport Rates from Elevator to Market, by Vehicle Type

	Semi-truck rate to	Rail rate to

Origin	Cedar Rapids	East Clinton	Iowa Falls	East Clinton	Iowa Falls
Marshalltown	$136.00	$302.00	$108.00		
Liscomb	166.00	332.00	98.00	$842.80	$588.00
Rinard	330.00	502.00	140.00		
Farnhamville	314.00	486.00	140.00	842.80	627.20

CHAPTER 4: RESULTS

Base solution

This solution attempts to mimic the grain industry under the assumption that quality differentiated corn and soybeans are available today. The model was constrained to reflect current grain-flow patterns. The first two constraints, regarding the cultivation practices of each farm, have already been explained in the farm-level data section in Chapter 3. The Marshall County farm operates on a corn/corn/soybean crop rotation and the Webster-Calhoun farm operates on a corn/soybean rotation. Each farm is assumed to have 1,000 acres of farmable ground. 1992 *U.S. Census of Agriculture* data estimates the average farm size to be 300 acres. However, the census data includes small part-time and hobby farmers who use farming to supplement other sources of income, implying these farms represent large scale operations.

Processing capacities in this base solution have been constrained as described in the processing section of Chapter 4. Corn processing capacity of the wet-mill plant in Cedar Rapids was set at 200,000 bpd, and soybean processing capacity of the plant in Iowa Falls was set equal to 68,000 bpd. Current corn processing capacity is approximately 33 percent of the state of Iowa's corn production. Hence, only 33 percent of the corn grown in the model was allowed to flow to the processor. Similarly, approximately 75 percent of the soybeans in the state are processed in Iowa. Thus, only 75 percent of the soybeans produced in the model were allowed to flow to the processor in Iowa Falls.

Livestock production was constrained to current levels. For Marshall County, the farm was allowed to produce 1,159 grain consuming units, and the Webster-Calhoun farm was allowed to produce 668 grain consuming units (see Appendix A). These figures were estimated by multiplying each farm's share of total county acres by the total number of grain consuming units produced in each county. The farm in Marshall County composed 0.44 percent of the total acres harvested for grain within the county. The farm in Webster-Calhoun counties composed 0.15 percent of the total acres harvested for grain in the two counties.

Corn and soybean shipments from farms were also constrained by vehicle type. Of the corn shipped off the Marshall County farm, 25.4 percent was shipped by a tractor pulling two 300 bushel wagons and 74.6 percent was shipped by semi. For soybeans, 32.6 percent was shipped by tractor-wagon with the remainder being shipped by semi. For Webster-Calhoun counties, 44.8 percent of the corn and 47.5 percent of the soybeans were shipped off the farm by tractor-wagon with the remainder shipped by semi [Baumel et al. (1996)].

Table 27 presents the corn and soybean production by variety. The farm in Marshall County produced 53,453 bushels of wet-mill corn, 19,172 bushels of feed corn, 3,688 bushels of generic corn, and 14,333 bushels of high-protein soybeans. Similarly, the farm in Webster-Calhoun counties produced 26,923 bushels of wet-mill corn, 17,227 bushels of feed corn, 21,850 bushels of generic corn, 10,792 bushels of high-protein soybeans, and 9,208 bushels of generic soybeans.

TABLE 27 Corn and Soybean Production, by Variety, for the Farms in Marshall County and Webster-Calhoun counties (Bushels)

	Corn			Soybeans		
Farm	Wet-mill	Feed	Generic	High-protein	High-oil	Generic
Marshall	53,453	19,172	3,688	14,333	0	0
Webster-Calhoun	26,923	17,227	21,850	10,792	0	9,208

Table 28 presents the feed quantity fed to livestock on a per head basis. Both farms produced livestock up to their total capacity—the farm in Marshall County produced 1,159 head of livestock and the farm in Webster-Calhoun counties produce 668 head.

Livestock in Marshall County consumed 241 pounds (4.3 bushels) of wet-mill corn, 926 pounds (16.5 bushels) of feed corn, 375 pounds of silage, 53 pounds of 44 percent soybean meal, and one pound of synthetic methionine per head. Livestock in Webster-Calhoun counties consumed 1,444 pounds (25.7 bushels) of feed corn and 84 pounds of 44 percent soybean meal. The corn consumption patterns for these two farms are reasonable according to Lawrence et al. (1994). In their report, corn consumption by livestock ranged from four bushels per head for lamb-fed to 89 bushels per head for dairy cows.

TABLE 28 Livestock Feed Ration Mixture per Animal, by Farm (Pounds)

Feed component	Marshall County farm	Webster-Calhoun counties farm
Wet-mill corn	241	0
Feed corn	926	1,444
Generic corn	0	0
Corn-gluten feed	0	0
Corn-gluten meal	0	0
Silage	375	0
44% Soybean meal	53	84
48% Soybean meal	0	0
Lysine	0	0
Methionine	1	0

Table 29 presents corn and soybean shipments off farms by crop variety. The farm in Marshall County shipped 38,899 bushels of wet-mill corn to the wet-mill processor in Cedar Rapids. It also shipped 9,556 bushels of wet-mill corn to the truck elevator in Marshalltown. The Marshall County farm also shipped 3,688 bushels of generic corn to the rail elevator located in Liscomb. Of the entire high-protein soybean crop, 9,661 bushels of high-protein soybeans were shipped direct to the soybean processor located in Iowa Falls, while the rest was shipped to the truck elevator in Marshalltown.

The farm in Webster-Calhoun counties produced 26,923 bushels of wet-mill corn and shipped the entire quantity to the elevator in Farnhamville. The entire 21,850 bushels of generic corn produced were also shipped to the rail elevator in Farnhamville. Of the entire high-protein soybean crop, 10,500 bushels were shipped directly to the processor in Iowa Falls, while 292 bushels were shipped to Farnhamville. The remaining generic soybean crop (9,208 bushels) was shipped to the elevator in Farnhamville.

It is interesting to note that the truck elevator located in Marshalltown did receive some grain while the truck elevator in Rinard did not receive any grain. This was because the elevators in Marshall County are located close to both the processors and the export market. In Marshall County, truck grain can successfully compete with rail grain. In Webster-Calhoun counties, the distance to processing and export markets forces grain to move by the more efficient rail.

TABLE 29 Corn and Soybean Shipments from Farm, by Market and Variety (Bushels)

Crop	Farm	Truck elevators		Rail elevators		Processors	
		Marshalltown	Rinard	Liscomb	Farnhamville	Cedar Rapids	Iowa Falls
Wet-mill corn	Marshall	9,556	0	0	0	38,899	0
	Webster-Calhoun	0	0	0	26,923	0	0
Feed corn	Marshall	0	0	0	0	0	0
	Webster-Calhoun	0	0	0	0	0	0
Generic corn	Marshall	0	0	3,688	0	0	0
	Webster-Calhoun	0	0	0	21,850	0	0
High-protein soybeans	Marshall	4,673	0	0	0	0	9,661
	Webster-Calhoun	0	0	0	292	0	10,500
High-oil soybeans	Marshall	0	0	0	0	0	0
	Webster-Calhoun	0	0	0	0	0	0
Generic soybeans	Marshall	0	0	0	0	0	0
	Webster-Calhoun	0	0	0	9,208	0	0

Table 30 presents the quantity of grain shipped off farms by both grain variety and vehicle type. Of the grain moving off the farm in Marshall County, 38,899 bushels of wet-mill corn and 9,661 bushels of high-protein soybeans moved by semi; 9,556 bushels of wet-mill corn, 3,688 bushels of generic corn, and 4,673 bushels of high-protein soybeans moved by tractor-wagon. Of the grain moving off the farm in Webster-Calhoun counties, 26,923 bushels of wet-mill corn and 10,500 bushels of high-protein soybeans moved by semi; 21,850 bushels of generic corn, 292 bushels of high-protein soybeans, and 9,208 bushels of generic soybeans moved by tractor-wagon. Essentially both farms shipped as much grain as possible by semi, with the rest constrained to move by tractor-wagon.

Table 31 presents the quantity of corn and soybeans shipped from elevators, by market. Of the grain leaving the Marshalltown elevator, 9,556 bushels of wet-mill corn were trucked to the wet-mill processor in Cedar Rapids and 4,673 bushels of high-protein soybeans were trucked to the soybean processor in Iowa Falls. The elevator in Liscomb railed 3,689 bushels of generic corn for export. The elevator in Farnhamville shipped a combined total of 58,272 bushels of grain. Farnhamville shipped 26,922 bushels of wet-mill corn and 21,850 bushels of generic corn for export, 292 bushels of high-protein soybeans to the processor in Iowa Falls, and 9,208 bushels of generic soybeans for export. All of the grain shipped from the Farnhamville elevator for export moved by rail car.

TABLE 30 Corn and Soybean Shipments from Farms, by Vehicle Type (Bushels)

Crop	Farm	Tractor-two wagons	Semi
Wet-mill corn	Marshall	9,556	38,899
	Webster-Calhoun	0	26,923
Feed corn	Marshall	0	0
	Webster-Calhoun	0	0
Generic corn	Marshall	3,688	0
	Webster-Calhoun	21,850	0
High-protein soybeans	Marshall	4,673	9,661
	Webster-Calhoun	292	10,500
High-oil soybeans	Marshall	0	0
	Webster-Calhoun	0	0
Generic soybeans	Marshall	0	0
	Webster-Calhoun	9,208	0

TABLE 31 Corn and Soybean Shipments from Elevator, by Market (Bushels)

Crop	Elevator	Cedar Rapids	Iowa Falls	Export
Wet-mill corn	Marshalltown	9,556	0	0
	Liscomb	0	0	0
	Rinard	0	0	0
	Farnhamville	0	0	26,922
Feed corn	Marshalltown	0	0	0
	Liscomb	0	0	0
	Rinard	0	0	0
	Farnhamville	0	0	0
Generic corn	Marshalltown	0	0	0
	Liscomb	0	0	3,689
	Rinard	0	0	0
	Farnhamville	0	0	21,850
High-protein soybeans	Marshalltown	0	4,673	0
	Liscomb	0	0	0
	Rinard	0	0	0
	Farnhamville	0	292	0
High-oil soybeans	Marshalltown	0	0	0
	Liscomb	0	0	0
	Rinard	0	0	0
	Farnhamville	0	0	0
Generic soybeans	Marshalltown	0	0	0
	Liscomb	0	0	0
	Rinard	0	0	0
	Farnhamville	0	0	9,208

Table 32 presents a list of the products produced at the corn wet-miller located in Cedar Rapids. The processor wet-milled 48,455 bushels of wet-mill corn. By-products of the wet-mill process accounted for 97,685 pounds of corn oil, 516,530 pounds of gluten feed, and 98,364 pounds of gluten meal. Starch production was 1,675,089 pounds, all of which was converted to 1,770,600 pounds of glucose. The glucose was then converted to HFCS 55. There were 1,770,600 pounds of HFCS 55 produced. No ethanol was produced because the price of ethanol in the model was set at $1.15, and it cost the processors $1.78 to produce one gallon of ethanol from glucose. The reason that this negative profit can exist is that the blender of the ethanol receives a subsidy for using ethanol. This subsidy was not in place in the model. Consequently, the products produced for sale or feed were corn oil, gluten feed and meal, and HFCS 55.

TABLE 32 Quantity of Output Produced from Processing Corn, by Corn Variety (Pounds)

Corn variety	Wet-mill corn	Feed corn	Generic corn
Corn oil	97,685	0	0
Gluten feed	516,530	0	0
Gluten meal	98,364	0	0
Starch	1,675,089	0	0
Glucose	1,770,600	0	0
HFCS 55	1,770,600	0	0
Ethanol	0	0	0

Table 33 presents the quantity of products produced by the soybean processor located in Iowa Falls. The processor crushed 25,125 bushels of high-protein soybeans. The crush yielded 243,710 pounds of soybean oil and

1,334,100 pounds of 44 percent protein soybean meal. No 48 percent protein soybean meal was produced. While the price of high-protein soybean meal was 0.61 cents higher, it does not compensate for the decrease in quantity from not being able to add the hulls back into the meal, as is done in 44 percent protein soybean meal.

TABLE 33 Quantity of Output Produced from Processing Soybeans, by Soybean Variety
(Pounds)

	Soybean variety		
Product	High-protein	High-oil	Generic
Soybean oil	243,710	0	0
Soybean meal 44%	1,334,100	0	0
Soybean meal 48%	0	0	0

Table 34 presents the average value per bushel for each of the three varieties within a crop for each farm, by end-use. The values are calculated as if each bushel of grain was used by the target end-user (i.e., processing values were estimated for each farm as if the corn were processed). Value in this case is profit per bushel above and beyond production, distribution, and processing costs. For the entire system, it was most profitable to have both farms produce wet-mill corn for future processing in Cedar Rapids. This sequence of activities resulted in $4.31 profit per bushel in Marshall County and $4.31 profit per bushel in Webster-Calhoun counties. These values were calculated on only the wet-mill corn processed in Cedar Rapids.

TABLE 34 Average Value per Bushel of Grain, by Farm, Variety, and End-Use

			Farm			
			Marshall		Webster-Calhoun	
Crop	End-use	Variety	Direct	Elevator	Direct	Elevator
Corn	Processing	Wet-mill	$4.31	$4.14	$4.31	$4.18
		Feed	4.06	3.89	4.06	3.93
		Generic	4.14	3.97	4.14	4.01
	Feed	Wet-mill	0.73	n/a	1.01	n/a
		Feed	0.73	n/a	1.01	n/a
		Generic	0.73	n/a	1.01	n/a
	Export	Wet-mill	0.38	0.29	0.37	0.50
		Feed	0.38	0.29	0.37	0.50
		Generic	0.38	0.29	0.37	0.50
Soybeans	Processing	High-protein	2.89	2.72	2.63	2.46
		High-oil	2.37	2.20	2.11	1.94
		Generic	2.72	2.55	2.46	2.29
	Export	High-protein	2.31	2.24	1.85	2.01
		High-oil	2.31	2.24	1.85	2.01
		Generic	2.31	2.24	1.85	2.01

While the farm in Webster-Calhoun counties did not ship corn to the processor, the value on the wet-mill variety was calculated as if the corn was processed. These values do not represent wet-mill corn which was exported. One would think that since the farm in Marshall County is closer to the processor that its per bushel profit would be higher than those of the farm in Webster-Calhoun counties. However, remember that the farm in Marshall County plants on a corn/corn/soybean rotation whereas the farm in Webster-Calhoun counties produces on a corn/soybean rotation. The difference in rotations makes it approximately 20 cents per bushel more expensive to produce corn in Marshall County.

The next most valuable corn activity was to produce feed corn for livestock consumption. The values in Table 34 are the average value per bushel of corn, given that the feed corn was fed to livestock in local markets. It resulted in 73 cents profit per bushel to the farm in Marshall County and $1.01 profit per bushel to the farm in Webster-Calhoun counties. Again, the big difference in values is a result of the crop rotation schemes of each county. Another reason for the difference was that the return to livestock net of non-feed costs was approximately the same, but it took fewer bushels of corn per head to feed livestock in Webster-Calhoun counties. Differences between varieties could not be made because each farm fed several feed ingredients to livestock, clouding the issue of value to any one feed ingredient.

Finally, the value of exporting corn was approximately 29 cents per bushel in Marshall County and 50 cents per bushel in Webster-Calhoun counties. It is interesting to note that had the corn for export in Marshall County been shipped direct from farms, the per bushel profit derived from export corn would have increased by nine cents. However, the fact that the model chose to ship the corn via the elevator stems from the initial vehicle constraint that 25.4 percent of the corn shipped off farms was required to move by tractor-wagon. Shipping one bushel of corn to export direct would have forced one bushel of wet-mill corn to pass through the elevator rather than move direct, resulting in a 17 cent per bushel reduction in profit. Thus, overall profits would have decreased by eight cents.

Soybean production costs totaled $197.92 per acre. Since Marshall County experienced yields of 43 bushels per acre and Webster-Calhoun counties experienced yields of 40 bushels per acre, the production costs per bushel were 24.9 cents per bushel higher in Webster-Calhoun counties. This difference in production costs accounts for most of the differences in variety values across farms. The value of high-protein soybeans produced on the farm in Marshall County was $2.89, while the value of those produced on the farm in Webster-Calhoun counties was $2.63—a difference of 26 cents. The remainder of the difference is a result of the difference in transportation costs. It costs approximately 1.6 cents per bushel more to ship a bushel of soybeans from the farm in Webster-Calhoun counties than from the farm in Marshall County.

After the processor, the next alternative is the export market, where soybeans were not differentiated by intrinsic quality. The value of soybeans produced for export on the farm in Marshall County is $2.24 per bushel. The value of soybeans produced for export on the farm in Webster-Calhoun counties is $2.01. The difference between farms is 23 cents per bushel, which is less than the 24.9 cent difference in production costs. This is because grain shipped to export must pass through the elevators in the model. The farm in Marshall County shipped grain to Liscomb, and the farm in Webster-Calhoun counties shipped grain to Farnhamville. The handling costs at the elevator in Liscomb were approximately two cents higher than the handling costs in Farnhamville. Thus, handling costs account for the different values across farms.

Table 35 presents the shadow values associated with each of the constraints imposed on the solution. The first two rows in Table 35 indicate the cost to the system of producing grain on a sustainable basis. In other words, for the last acre of land planted, this constraint indicates the change in profit from forcing corn and soybeans to be grown simultaneously in a rotation pattern rather than simply producing the most profitable crop alone. A negative value represents a decrease in profit or a cost to the system. For the farm in Marshall County, the cost of complying with the cultivation practice was $17.75 per acre. In Webster-Calhoun counties, the cost imposed by the cultivation practice was $8.97 per acre.

TABLE 35 Shadow Values Associated with Base Solution Constraints

Constraint	Shadow value
Marshall cultivation practice	-17.75
Webster-Calhoun cultivation practice	-8.97
Corn processing capacity	4.10
Soybean-processing capacity	0.50
Marshall livestock	11.41
Webster-Calhoun livestock	14.67
Marshall corn transport	-0.17
Marshall soybean transport	-0.16
Webster-Calhoun corn transport	-0.02
Webster-Calhoun soybean transport	-0.17

The shadow price associated with corn processing capacity was estimated at $4.10. This value is the amount of money that profits would increase if the model were allowed to process one more bushel of corn. Relaxing the corn processing constraint has the highest value of all of the constraints in the model, from a value per bushel standpoint. Similarly, for soybeans, the shadow price that accrued to soybean processing capacity was $0.50. The shadow prices associated with Marshall County livestock and Webster-Calhoun counties livestock were $11.41

and $14.67, respectively. The four remaining constraints relate to the quantities of corn and soybeans shipped off farms by tractor-wagon. If the farms shipped one additional bushel of grain by tractor-wagon, profits would decrease 16–17 cents per bushel. This cost represents the additional elevator costs, since the extra bushel shipped by tractor-wagon previously moved by directly to the processor by semi and tractor-wagon grain goes to the elevator. The cost of the tractor-wagon corn constraint to Webster-Calhoun counties was only two cents because most all of the corn moving off farms already passed through the elevator. Thus, the extra two cent cost is simply the difference in transportation costs from shipping corn to Farnhamville in a tractor-wagon rather than in a semi.

Long-run solution

This long-run solution assumes that, over time, the markets have adjusted capacities in order to handle quality differentiated grains. However, the constraint on cultivation practices is still in place. Table 36 presents the quantity of each variety of corn and soybeans produced by each farm. As expected, both farms produced wet-mill corn only. The farm in Marshall County produced 81,333 bushels of wet-mill corn, and the farm in Webster-Calhoun counties produced 66,000 bushels. Similarly, both farms produced only high-protein soybeans. The farm in Marshall County produced 14,333 bushels of high-protein soybeans, and the farm in Webster-Calhoun counties produced 20,000 bushels.

TABLE 36 Corn and Soybean Production, by Variety, for One Farm in Marshall County and
Webster-Calhoun Counties (Bushels)

	Corn			Soybeans		
Farm	Wet-mill	Feed	Generic	High-protein	High-oil	Generic

Marshall	81,333	0	0	14,333	0	0
Webster-Calhoun	66,000	0	0	20,000	0	0

Table 37 presents livestock production by each market and the feed ration used to raise one head of livestock. Only the farm in Marshall County produced livestock (985 head). These animals were fed only corn-gluten feed from the corn wet-miller. Each animal consumed 1,595 pounds of corn-gluten feed.

TABLE 37 Livestock Production and Ration Mixture per Animal, by Market

		Feed ration per animal		
Market	Number of grain consuming units	Wet-mill corn (bushels)	Feed corn (bushels)	Gluten feed (pounds)
Marshall	985	0	0	1,595
Webster-Calhoun	0	0	0	0

Table 38 presents the quantities of corn and soybeans shipped off-farm, by market. Given the results in the base solution, it is not surprising that both farms shipped their entire crop of wet-mill corn direct to the corn wet-miller in Cedar Rapids.

TABLE 38 Corn and Soybean Shipments from Farms, by Market and Variety (Bushels)

		Truck elevators		Rail elevators		Processors	
Crop	Farm	Marshalltown	Rinard	Liscomb	Farnhamville	Cedar Rapids	Iov Fal
Wet-mill corn	Marshall	0	0	0	0	81,333	
	Webster-Calhoun	0	0	0	0	66,000	
Feed corn	Marshall	0	0	0	0	0	
	Webster-Calhoun	0	0	0	0	0	
Generic corn	Marshall	0	0	0	0	0	

	Webster-Calhoun	0	0	0	0	0	
High-protein soybeans	Marshall	0	0	0	0	0	14,3
	Webster-Calhoun	0	0	0	0	0	20,(
High-oil soybeans	Marshall	0	0	0	0	0	
	Webster-Calhoun	0	0	0	0	0	
Generic soybeans	Marshall	0	0	0	0	0	
	Webster-Calhoun	0	0	0	0	0	

The farm in Marshall County shipped 81,333 bushels of wet-mill corn, and the farm in Webster-Calhoun counties shipped 66,000 bushels. Similarly, both farms shipped their entire crop of high-protein soybeans direct to the soybean processor in Iowa Falls. The farm in Marshall County shipped 14,333 bushels of high-protein soybeans, and the farm in Webster-Calhoun counties shipped 20,000 bushels.

Table 39 presents the quantities of corn and soybeans shipped off-farm, by both vehicle type and grain variety. Both farms shipped their entire crop of both wet-mill corn and high-protein soybeans direct to processors in semis. Again this is not surprising, since it costs 0.1 cents per bushel more to transport grain via tractor and two wagons than via semi.

TABLE 39 Corn and Soybean Shipments from Farms, by Vehicle Type and Grain Variety (Bushels)

Crop	Farm	Tww	Semi
Wet-mill corn	Marshall	0	81,333
	Webster-Calhoun	0	66,000
Feed corn	Marshall	0	0

	Webster-Calhoun	0	0
Generic corn	Marshall	0	0
	Webster-Calhoun	0	0
High-protein soybeans	Marshall	0	14,333
	Webster-Calhoun	0	20,000
High-oil soybeans	Marshall	0	0
	Webster-Calhoun	0	0
Generic soybeans	Marshall	0	0
	Webster-Calhoun	0	0

Table 40 presents a list of the products produced at the corn wet-miller in Cedar Rapids. The processor produced 147,333 bushels of wet-mill corn. By-products of the wet-mill process accounted for 297,020 pounds of corn oil, 1,570,600 pounds of gluten feed, and 299,090 pounds of gluten meal. Starch production was 5,093,300 pounds that was subsequently converted to 5,383,600 pounds of glucose. The glucose produced 5,383,600 pounds HFCS 55. Again, no ethanol was produced because of the negative profit that exists, since the blender of the ethanol receives a subsidy.

TABLE 40 Quantity of Output Produced from Processing Corn, by Corn Variety (Pounds)

Corn variety	Wet-mill corn	Feed corn	Generic corn
Corn oil	297,020	0	0
Gluten feed	1,570,600	0	0
Gluten meal	299,090	0	0
Starch	5,093,300	0	0
Glucose	5,383,600	0	0

HFCS 55	5,383,600	0	0
Ethanol	0	0	0

Table 41 presents the quantity of products produced by the soybean processor located in Iowa Falls. The processor crushed 34,333 bushels of high-protein soybeans. The crush yielded 333,030 pounds of soybean oil and 1,823,100 pounds of 44 percent protein soybean meal. Again, the processor did not produce 48 percent protein soybean meal because the higher price of high-protein meal does not compensate for the decrease in quantity from not being able to add the hulls back into the meal, as in the case of the 44 percent protein meal.

TABLE 41 Quantity of Output Produced from Processing Soybeans, by Soybean Variety (Pounds)

	Soybean variety		
Product	High-protein	High-oil	Generic
Soybean oil	333,030	0	0
Soybean meal 44%	1,823,100	0	0
Soybean meal 48%	0	0	0

Table 42 presents the shadow values by farm for producing an acre of each variety of grain. These shadow values represent the amount of money that profits for the system would change when one acre of a non-optimal variety of grain was produced. In the long run, the quality of feed corn and high-oil corn crops are less valuable per acre than the generic varieties. This result stems from the fact that when maximizing profits in the long run, the integrated firm is interested in maximizing the production of HFCS 55, which is the same as maximizing corn starch production. With this goal in mind, the three corn varieties can be ranked by their starch content as follows: 1) wet-mill (63 percent), 2) generic (60 percent), and 3) feed (58.5 percent). Similarly, in the case of soybean processing, the firm is interested in maximizing soybean meal output or protein output. Ranking the three soybean varieties by protein content yields 1) high-protein (38 percent), 2) generic (35.5 percent), and 3) high-oil (31.6 percent).

TABLE 42 Shadow Values per Acre of Production, by Farm and Variety (Dollars per Acre)

		Farm	
Crop	Variety	Marshall	Webster-Calhoun
Corn	Wet-mill	$ 0	$ 0
	Feed	-30.19	-32.67
	Generic	-19.94	-21.57
Soybeans	High-protein	0	0
	High-oil	-22.29	-20.73
	Generic	-7.43	-6.92

When comparing these shadow prices, it is important to remember that the shadow value of a non-optimal variety is relative to the optimal variety of grain grown within the same farm or county. When comparing the shadow values of high-oil soybeans across farms, one cannot say that it is more profitable to grow soybeans in Webster-Calhoun counties simply because the shadow price on an acre of high-oil soybeans is $1.56 higher. Since processed soybean output prices are not based on the variety nor the origin of the soybeans, the revenue from processing a bushel of soybeans is the same across farms, holding the variety fixed on both farms. The costs of production and distribution, however, are higher for the farm in Webster-Calhoun counties. Recall the production costs per acre of soybeans was set equal to $142.83. Given yields of 42 bushels per acre for the farm in Marshall County and 40 bushels per acre for the farm in Webster-Calhoun counties, it is more expensive to produce soybeans in Webster-Calhoun counties on a per bushel basis. Moreover, the farm in Webster-Calhoun counties is eight miles farther from the processor than the farm in Marshall County, which costs the farm in Webster-Calhoun counties more to transport soybeans to the processor. Therefore, without being given the optimal value of the soybeans, comparison across farms using Table 41 is difficult.

Table 43 converts the per acre shadow values in Table 41 to per bushel shadow values for each variety of grain, by farm. Surprisingly, the shadow values in Table 42 for the corn varieties are exactly the same across farms. This results from the fact that, holding the variety fixed across farms, each bushel of corn processed by the corn wet-miller has the same return per bushel, regardless of the origin of the corn. Combining the cultivation practices of each farm with its corresponding transport costs, the costs to produce and distribute corn to the wet-miller are the same across farms. Consequently, on a per bushel basis, there is no difference in per bushel revenue, cost, and profit across farms. Hence, each farm experiences the same per bushel shadow values for producing corn.

TABLE 43 Shadow Values of Grain, by Farm and Variety (Cents per Bushel)

		Farm	
Crop	Variety	Marshall	Webster-Calhoun
Corn	Wet-mill	¢ 0	¢ 0

	Feed	-24.75	-24.75
	Generic	-16.34	-16.34
Soybeans	High-protein	0	0
	High-oil	-53.07	-51.83
	Generic	-17.69	-17.30

CHAPTER 5: DISCUSSION

Localization of production

The localization of production can be seen most clearly by examining the production practices relating to wet-mill corn. From Table 34, it is clear that the farm in Webster-Calhoun counties had a comparative advantage in grain for livestock and export. While not as great, the farm in Marshall County had a slight comparative advantage in producing wet-mill corn. Moreover, the farm in Marshall County lies on the border of farms that possessed a comparative advantage in wet-mill corn production over the farm in Webster-Calhoun counties. If the farm in Marshall County had been four miles west of its location in the model, the comparative advantage would have been reversed.

Given this list of comparative advantages, it was not surprising that the farm in Marshall County produced wet-mill corn and shipped it directly to the processor in Cedar Rapids. The farm in Marshall County was capable of completely satisfying the corn demands of the wet-miller. Hence, the farm in Webster-Calhoun counties did not produce wet-mill corn for shipment to the processor. From this perspective, the production of wet-mill corn for processing was centralized around the corn wet-miller.

The farm in Marshall County lies on border of farms possessing a comparative advantage in wet-mill corn production over the farm in Webster-Calhoun counties. From the perspective of a central planner, moving the farm in Marshall County away from the processor would have had no effect on the results, on a variety location basis. The farm with the competitive advantage in a variety is not necessarily the farm which produces that variety. For example, if the farm in Marshall County were moved five miles further away from the corn wet-miller, its value per bushel falls from $4.31 to $4.30. This value is lower than the value of growing wet-mill corn on the farm in Webster-Calhoun counties, implying the farm in Webster-Calhoun counties now has a competitive advantage in producing wet-mill corn. The central planner, however, would still dictate that the farm in Marshall County should grow the wet-mill corn.

From Table 34 the next best alternative to growing wet-mill corn and shipping it to the wet- miller for the Marshall County farm, assuming livestock production is already at its maximum, is to grow generic corn and ship it for export. This results in a per bushel loss of $4.01. Replacing the generic corn grown in Webster-Calhoun counties for export with the wet-mill corn grown for processing nets the system $3.81 per bushel. Clearly, even with the competitive advantage in the production of all three varieties of corn, growing the wet-mill corn in Webster-Calhoun counties costs the system more than growing it in Marshall County. Hence, the central planner looking at the problem from a systems perspective grows the wet-mill corn in Marshall County even though the farm in Webster-Calhoun counties has the comparative advantage. Consequently, production of grain aimed at processing markets concentrates around the target processor.

Role of elevators and railroads

One of the striking features in the results is the limited role that elevators and railroads play in the model. From the central planner's perspective, moving grain to these quality markets via the elevator resulted in double handling and testing of the grain. If we assume that grain travels the same distance regardless of whether it travels direct to the processor or through the elevator, then this double handling and testing of grain is an unnecessary cost. Moreover, railroads face fierce competition from trucks on short grain movements. Thus, bypassing the elevator translates into bypassing the railroads in the quality markets.

Interpreting these results to say that elevators will play no role in a quality differentiated system, however, is incorrect. There are several caveats that need to be addressed. First, grain producers were allowed to transport their grain direct from farm to processor. This is not a common practice in today's market because processors prefer to deal with elevators rather than individual farmers. The reason is that elevators, while not modeled, perform a task that adds value to grain (i.e., they accumulate grain). By doing so, they can reduce the contracting costs of the processor because they can replace the many small contracts of individual farmers with one or few contracts with elevators. Consequently, elevators whose incremental per bushel handling and testing costs are smaller than the per bushel savings from replacing many small farmer contracts with larger elevator contracts will be able to participate in the quality differentiated system.

Second, elevators may be able to participate in a quality differentiated system if distant markets for quality grain exist. Albeit farmers in the model were not allowed to ship direct to the barge terminal in East Clinton, grains moving to the undifferentiated export market moved entirely by rail. If we assume that the truck transport costs from farm to export are the same as the rail transport costs from farm to elevator, then, in the worst case, it is roughly 36 cents per bushel cheaper to ship by rail. All of the elevators in the model have testing and handling costs less than 15.5 cents per bushel. Thus, for distant markets, elevators have an advantage over direct farm shipments, in terms of transport rates.

Who gets the added value per bushel?

Short-run

Table 34 presented the profits per bushel from producing, feeding, and processing all varieties of corn and soybeans. These profits per bushel are profits to the system, not to any one player in the market. The pressing question from grain producers is, “What will be the premium for producing these high quality grains?” End-users ask the related question, “How much extra will I have to pay in order to procure the quantity of grain I desire?” Both of these questions address the issue of how will the added value of quality differentiated grains be split among market players. This is a market power issue.

The farmer has the potential to capture some of the added values presented in Table 34, but it is the grain processors in the model who are the true short-run winners. In the market today, corn harvested is first fed to livestock because that demand is perfectly inelastic. Once the feed demand is met, farmers turn to the corn processor or export market to sell their corn. Typically, corn processors keep their plants running 24 hours a day for 350 days a year, implying that processing demand for corn is not very elastic. Corn produced in excess of these two markets is typically exported (Industry Sources).

The corn processor's direct competitor for grain is the export market which, in the model, pays $2.38 per bushel for corn. For discussion purposes, assume the elevator takes no profit from moving grain and there are no transportation costs. In this case, the farm in Marshall County nets an approximate per bushel profit of 29 cents for selling to the export market. Consequently, the corn miller in Cedar Rapids only has to pay the farmer $2.39 per bushel, ignoring transportation costs, to draw grain away from the export market.

In contrast, farmers can capture the entire added value of the feed variety of corn. This stems from the fact that the farmer is both the producer and end-user of the grain. Consequently, he does not have to share the added value with anyone. Therefore, the farm in Marshall County can capture $0.73 per bushel of feed corn, and the farm in Webster-Calhoun counties can capture $1.01 per bushel of feed corn.

The soybean market is more competitive than the corn market. In this case, the farmer stands a better chance of capturing the added value associated with each variety of soybeans. Currently, Iowa has the capacity to process 75 percent of the soybeans produced in the state. Farmers may be able to capture a greater share of the added value as a result of competition between firms, especially in areas where processors compete head-to-head in the procurement of soybeans. For example, farms in the Marshall County area may be able to capture almost all of the added value of high protein soybeans ($2.89) because the three processing firms—AGP, Cargill, and ADM—may bid up the price of soybeans in an attempt to keep their plants running at near full capacity.

Areas, however, where processing is dominated by one firm, like the area in Webster-Calhoun counties dominated by AGP, are less likely to capture the entire share of the high-protein soybeans due to the absence of direct competition for soybeans. In this case, the soybean processor merely has to pay farmers more than the $5.94 received at the export market. In the model, the farm in Webster-Calhoun counties would capture little more than $2.01 in added value, and the processors would get the remaining 62 cents. The fact that farmers are able to capture more than half of the added value of high-protein soybeans attests to greater competition in the soybean market.

Long run

In the long run, the model assumes that processing capacity in Iowa is great enough to process all of the corn and soybeans produced in a year. In this instance, if processing plants begin to compete with each other for corn and soybeans, it is likely that the farmer will be the beneficiary of a quality differentiated system. The farm in Marshall County would receive almost the entire value of $4.31 per bushel. The value of the feed and generic varieties of corn would increase to $4.06 per bushel and $4.15 per bushel, respectively. These values are nothing more than the processed values of these varieties. For the farm in Webster-Calhoun counties, the wet-mill corn would be valued at $4.31 per bushel, the feed corn would be valued at $4.06 per bushel, and the generic variety of corn would be valued at $4.15 per bushel. Assuming the corn processors have little market power, the farmer should be able to capture virtually the entire value per bushel.

In the soybean market, high-protein soybeans have a value of $2.89 per bushel from the farm in Marshall County and $2.63 per bushel from the farm in Webster-Calhoun counties. The high-oil soybean had a value of $2.37 per bushel from the farm in Marshall County and a value of $2.10 per bushel from the farm in Webster-Calhoun counties. Finally, the value of the generic variety of soybeans was $2.72 per bushel from the farm in Marshall County and $2.45 per bushel from the farm in Webster-Calhoun counties. In the absence of any market power, soybean processors will likely be forced to pay out the entire value per bushel to farmers.

Commodity based system vs. quality differentiated system

In order to determine whether the U.S. should pursue opportunities to shift from a commodity based logistics system to a quality differentiated logistics system, the short-run model was re-run where the generic varieties of corn and soybeans were the only varieties available. In this instance, system profits for a commodity based logistics system total approximately $359,714, whereas the short-run system profits in a quality differentiated logistics system totaled $372,512. This results in a net improvement to the system of $12,798.

Profits to the system increased from $372,512 in the quality differentiated short-run solution to $764,468 in the long-run solution. Since it is not clear how much of the increased profits will be gained by the grain producers in the model, grain producers must examine the short-run returns versus the long-run returns when determining whether or not is in their best interest to participate in a quality differentiated system. Given these results, it is plausible that a quality differentiated grain distribution system will evolve.

APPENDIX A

Grain consuming unit construction

In order to simplify the LP model, livestock classes were aggregated into grain consuming units. The grain consuming units were constructed from five livestock classes. Livestock classes included were beef-fed, dairy cattle, pork-sows, pork-fed, and lamb-fed. These five classes were chosen because they account for over 95 percent of the grain fed in Iowa. For modeling purposes, the number of head for each class of livestock was constructed by estimating the average head per livestock class over the time period 1991–1994.

Two local feed markets were constructed where grain producers also produce livestock. These two markets essentially boiled down to the farmer feeding corn to livestock. Livestock production numbers on grain-fed cattle and sheep marketed were used for beef-fed and lamb-fed. The number of milk cows on farms as of January 1 were used to estimate dairy cow production. Since county-level data on these ruminants were only available from the *1992 U.S. Census of Agriculture*, the state totals in the other years were scaled according to the census numbers.

Sows farrow roughly twice a year. Hence, pork-sow numbers were estimated as the average number of sows farrowed in the periods December–May and June–November. Pork-fed numbers were estimated by multiplying the average number of pigs per litter by the number of sows in production in each semester and summing over the semesters. Sow figures were not available at the county level except for *1992 U.S. Census of Agriculture* figures. Hence, state sow totals were scaled to Marshall and Webster-Calhoun levels according to the 1992 figures. Pigs per litter numbers were state averages. Table A1 lists the number of sows farrowed by semester, the average number of pigs per litter, and the total number of sows pork-fed, by market.

TABLE A1 Number of Sows Farrowed and Pork-Fed (Thousands of Head) and Average Number of Pigs per Litter, by Semester, 1991–1994

		Marshall		Webster-Calhoun		U.S.	
Year	Class	Dec–May	Jun–Nov	Dec–May	Jun–Nov	Dec–May	Jun–Nov
1991	Sows	14.07	15.45	24.17	25.12	4,719	4,797
	Pigs/litter	7.86	7.68	7.86	7.68	7.93	7.90
	Pork-fed	110.62	118.68	189.95	192.95	37,422	37,896
1992	Sows	15.20	14.70	26.10	23.90	4,954	4,741
	Pigs/litter	8.10	8.10	8.10	8.10	8.09	8.11
	Pork-fed	123.12	119.07	211.41	193.59	40,078	38,450
1993	Sows	13.70	14.45	23.52	23.49	4,751	4,698
	Pigs/litter	8.14	7.95	8.14	7.95	8.15	8.07
	Pork-fed	111.51	114.87	191.47	186.76	38,721	37,913
1994	Sows	13.70	13.40	23.52	21.78	4,969	4,773
	Pigs/litter	8.12	8.05	8.12	8.05	8.12	8.22
	Pork-fed	111.23	107.83	191.00	175.32	40,348	39,243

Table A2 lists the annual livestock production numbers used in the model [U.S. Agricultural Statistics (1995) and Iowa Agricultural Statistics (1994,1995)]. Over the period 1991–1994, livestock figures remained relatively constant. On a per head basis, pork-fed is by far the predominant class of livestock in Marshall County and Webster-Calhoun counties. At the national level, however, beef-fed holds a larger share of the market, on a per head basis. Except for pork-fed, Marshall County livestock numbers are close in magnitude to livestock numbers in Webster-Calhoun counties, even though Webster-Calhoun is comprised of two counties. This tends to imply that Marshall County has a comparative advantage in growing livestock.

Table A3 identifies the animal attributes of each livestock class, including average weight and number of days on feed. Only two classes of livestock (pork-sows and dairy cattle) were assumed to be on feed the entire year. These animals are not slaughtered for their meat but rather are used for breeding and milk production, respectively. Consequently, they are fed on a year-round basis. Beef-fed, pork-fed, and lamb-fed, on the other hand, are slaughter animals requiring less than one year to reach slaughter weights. Thus, these animals are fed only for a portion of the year.

Table A4 presents the daily nutrient requirements per animal for each class of livestock [National Research Council (1985, 1986, 1988)]. Nutrients included were dry matter, metabolizable energy, protein, lysine, and methionine. To calculate the annual nutrient requirements for the grain consuming unit, the daily nutrient requirements were multiplied by the number of head in the livestock class. This yields the total daily nutrient requirements for the entire livestock class within each livestock feed market. Summing across livestock classes yields the total daily nutrient requirements for a livestock market. Annual nutrient requirements for one grain consuming unit in each market were calculated by dividing the entire market's daily nutrient requirements by the total number of grain consuming units and multiplying by 365 days. The total number of grain consuming units in each market was equal to the total number of head of livestock in each market.

The annual nutrient requirements for one grain consuming unit are presented in Table A5. Grain consuming units in the Marshall and Webster-Calhoun markets, have the same relative nutrient requirements. Table A6 presents the livestock shares comprising the grain consuming units in each market.

TABLE A2 Livestock Production Numbers 1991–1994 (Thousands of Head)

Market	Class	1991	1992	1993	1994	Average
Marshall	Beef-fed	17	18	18	16	17
	Pork-sows	15	15	14	14	15
	Pork-fed	229	242	226	219	229
	Lamb-fed	5	3	5	3	4
	Dairy	1	1	1	1	1
Webster-Calhoun	Beef-fed	21	22	23	20	22
	Pork-sows	25	25	24	23	24
	Pork-fed	383	405	378	383	387
	Lamb-fed	8	6	7	5	7
	Dairy	1	1	1	1	1
United States	Beef-fed	55,466	55,197	55,701	56,194	55,640
	Pork-sows	4,758	4,876	4,848	4,746	4,807
	Pork-fed	75,318	77,974	78,527	77,170	77,247
	Lamb-fed	8,906	8,930	8,704	7,887	8,607
	Dairy	10,156	9,904	9,658	9,528	9,812

TABLE A3 Livestock Attributes, by Livestock Class

Livestock attribute	Beef-fed	Pork-sows	Pork-fed	Lamb-fed	Dairy

Average weight (lbs)	850	300	140	95	1,250
Days on feed	300	365	170	100	365

TABLE A4 Daily Nutrient Requirements, by Livestock Class

Nutrient	Beef-fed	Pork-sows	Pork-fed	Lamb-fed	Dairy
Dry matter (lbs)	20.40	9.09	5.60	2.38	37.50
Metabolizable energy (Mcal)	23.19	13.25	7.64	2.91	40.41
Protein (lbs)	1.84	1.14	0.73	0.28	4.91
Amino acids					
Lysine		0.0455	0.0392		
Methionine		0.0273	0.0213		

TABLE A5 Annual Nutrient Requirements for a Grain Consuming Unit, by Farm)

Nutrient	Marshall	Webster-Calhoun
Dry matter (lbs)	1,450.61	1,346.93
Metabolizable energy (Mcal)	1,890.32	1,779.41
Protein (lbs)	172.29	162.40
Amino acids		
Lysine (lbs)	6.64	6.77
Methionine (lbs)	3.66	3.73

TABLE A6 Livestock Shares Comprising One Grain Consuming Unit, by Farm

Livestock class	Marshall	Webster-Calhoun
Beef-fed	6.47	4.98
Pork-sows	5.38	5.51
Pork-fed	86.23	87.93
Lamb-fed	1.54	1.45
Dairy	0.38	0.14

APPENDIX B

Segregation of differentiated grains

The country elevator is the first point of sale for most grain originating in Iowa. Hence, it is the point in the distribution channel which experiences the greatest variation in quality [Hurburgh (1989)]. In order to capture the full processed value of a variety of grain, the segregation should take place at the country elevator. The costs of segregating grain will be facility specific. The characteristics describing elevators in Iowa are almost as numerous as the attributes related to grain quality. Iowa elevators were classified as large, moderate, and small; concrete or wood; rail loaders or truck shippers; land-locked; one dump pit or 10 dump pits; etc. The elevator characteristics listed play a significant role in determining the cost of segregating grain at each facility. For example, the number of pits and the ease of redirecting grain among storage units are parameters in determining if any additional costs will be incurred from differentiating grain.

The additional testing and segregation of quality differentiated grain is often considered to be a prohibitive cost for grain elevators. Operators of elevators with high turnover ratios are concerned about underutilizing costly space [Hurburgh et al. (1994)]. Given that the design and configuration of an elevator facility may play a significant role in the facility's cost of segregating grain, it is likely that the relative cost differences among elevators will cause shifts in the grain-flow patterns of producers. The following model identifies many of the costs likely to be encountered by local country elevators.

Fixed costs of segregating grain

The first group of costs are categorized as sunk costs from the perspective of the elevators. These are costs which do not vary with quantity of grain tested and segregated. Given that these costs are sunk, the annualized value of these costs is calculated in order to keep the model on an annual basis.

The first cost in this category, SC_1, is the cost of test equipment. Most of the early testing will be conducted using near-infrared (NIR) composition analyzers. This is a light absorbence technique working on either whole or ground grain. The salvage value of any equipment that has been eliminated by the NIR composition analyzer (e.g., moisture meters) is deducted from the annualized cost of test equipment.

$$SC_1 = \left[(P_t - P_t') \left\langle 1/(1+r)^n \right\rangle + P_t \left\langle (P_{rt}/100) + I/1000 \right\rangle \right] 1/V_t \qquad \textbf{(5)}$$

where:

P_t	=	purchase price of tester,
P_t'	=	salvage value of replace equipment,
P_{rt}	=	annual maintenance cost of tester (% of P_t),
I	=	insurance premium rate ($/$1,000),
r	=	long-run interest rate, and
V_t	=	volume of grain tested.

These new tests will require automated data handling, rather than manual transcription of the test results onto scale tickets. Personal computers will likely be connected to testing devices. In Equation 6, SC_2 represents the cost of automating the data transmission system.

$$SC_2 = \left[P_d \left\langle 1/(1+r)^n \right\rangle + P_d \left\langle (P_{rd}/100) + (I/1000) \right\rangle \right] 1/V_t \qquad \textbf{(6)}$$

where:

P_d	=	purchase price of data handling equipment, and

P_{rd} = annual maintenance cost of data handling equipment (% of P_d).

New data will also cause changes or upgrades in settlement and inventory control software that are amortized over the life of the test equipment. In Equation 7, SC_3 represents the cost of modifying in-house computer software.

$$SC_3 = \left[P_{cs}\left\langle 1/(1+r)^n \right\rangle + \left\langle p_u P_{cs}/100 \right\rangle\right] 1/V_t \quad \textbf{(7)}$$

where:

P_{cs} = purchase price new computer software, and

P_u = purchase price of computer software upgrades (% of PCs).

Elevators will be required to retain samples, if they do not already and if the new tests are price-determining. It is expected that disputes will arise with producers selling grain over the results of tests. These retained samples will be used to resolve these disputes by appeal or re-testing. In Equation 8, SC_4 represents the costs associated with sample storage.

$$SC_4 = \left[P_{ss}\left\langle 1/(1+r)^n \right\rangle\right] 1/V_t \quad \textbf{(8)}$$

where:

P_{ss} = price of constructing or remodeling sample storage area.

Some elevators may be required to modify dump pits, elevation legs, etc., in order to become more flexible and to switch more rapidly. In Equation 9, SC_5 represents the sunk costs associated with modifying the elevator's handling system.

$$SC_5 = \left[P_m\left\langle 1/(1+r)^n \right\rangle + P_m\left\langle \left(P_{rm}/100\right) + \left(I/1000\right)\right\rangle\right] 1/V_t \quad \textbf{(9)}$$

where:

P_m = price of modifying elevator design or configuration, and

P_{rm} = annual maintenance cost of modified design or configuration (% of P_m).

More individual storage with related handling equipment may be needed, even when the elevator is in overall excess. This is the item that causes the greatest fear among elevator operators and is frequently cited as a reason differentiated marketing will not work. A potential dilemma exists if the elevator must construct more storage sites to accommodate segregations while still possessing a net excess of storage by total volume. In Equation 10, SC_6 represents the sunk costs of storage for the elevator.

$$SC_6 = \left[P_s\left\langle 1/(1+r)^n\right\rangle + P_s\left\langle\left(P_{rs}/100\right) + \left(I/1000\right)\right\rangle\right]1/V_t \qquad \textbf{(10)}$$

where:

P_s = price of constructing new storage, and

P_{rs} = annual maintenance cost of new storage (% of P_s).

Variable costs of segregating grain

Any new tests create extra work in the testing area. The cost of these new tests is partially offset by some tests that are eliminated with the new system. In Equation 11, VC_1 represents additional operator time required at testing.

$$VC_1 = \frac{P_L\left(t_t - t_t'\right)}{60B} \qquad \textbf{(11)}$$

where:

P_L = price of labor,

t_t = time required for testing grain in a differentiated system,

t_t' = time required for testing grain in a commodity system, and

B = bushels represented per test.

Some additional costs will be required for accounting and record keeping, even if automated data handling exists. The dispatcher will have to make a decision and direct each load to its proper dump. A hard copy will probably be kept as a backup reference. In Equation 12, VC_2 represents the variable costs associated with accounting and record keeping.

$$VC_2 = \frac{P_L\left(t_a - t_a'\right)}{60B} \tag{12}$$

where:

t_a = accounting time required in a differentiated system, and

t_a' = accounting time required in a commodity system.

New tests will require monitoring to maintain accuracy. Sophisticated equipment such as near-infrared spectroscopy (NIRS) can drift off calibration. For example, the Federal Grain Inspection Services (FGIS) runs check and adjustment samples daily for its NIRS composition testing [FGIS (1990)]. Therefore, this work will consume additional time and expense. Elevator operators cannot neglect check testing/standardization because they cannot afford the risk of errors in factors that are price-determining. The most likely procedure for check testing will be submission of samples to a federal inspector or other analytical laboratory if the factors are not in the official standards. In Equation 13, VC_3 represents the variable cost of check-testing and standardization of equipment.

$$VC_3 = \frac{f_7}{100}\left\langle \frac{P_G}{B} + \frac{t_{aG}P_L}{60B} \right\rangle \tag{13}$$

where:

f_7 = percentage of sample sent for check test by FGIS,

P_G = cost of submitting sample grade, and

t_{aG} = accounting time for check test results.

Storage of samples has already been discussed in relation to their sunk costs. There is also a variable cost aspect of sample storage. In Equation 14, VC_4 represents the variable costs of sample storage.

$$VC_4 = \frac{t_S P_L}{60B} \quad \textbf{(14)}$$

where:

t_s = time required for placing samples in storage in a differentiated system.

A major reason elevator operators resist new tests is because potential for disputes with producers exist. Pricing all grain on the station average is simple and less risky than load-by-load analysis. Therefore, any market structure that increases the frequency of load-by-load price adjustment will create more time and expense in the dispute resolution. This cost will come in at least two forms: 1) elevator manager's time discussing questioned results, and 2) submitted appeal samples. In Equation 15, VC_5 represents the variable costs associated with disputes with producers.

$$VC_5 = \frac{f_9}{100}\left\langle \frac{P_{Lm} t_m}{60B} + \frac{P_G}{B} \right\rangle \quad \textbf{(15)}$$

where:

f_9 = percent of samples disputed by producers,

P_{Lm} = cost of manager's time,

t_m = manager's time spent dealing with disputes, and

P_G = costs of submitting sample grade.

Additional labor may be needed to accomplish the extra functions at dump pits. In Equation 16, VC_6 is the variable cost accounting for the additional labor required at the pits.

$$VC_6 = \frac{P_L}{V_G} + \frac{f_{11} P_L}{60B} \tag{16}$$

where:

V_G = volume of grain tested per year, and

f_{11} = subjective customer waiting time.

The probability that storage will be underutilized increases somewhat if grain is segregated by end-use value. Clearly, the number of segregations has to be set with consideration to the storage layout of the elevator. If the planned amount of grain storage is not received, then storage efficiency will be reduced. In conditions of excess storage capacity, this component could be zero. In Equation 17, VC_7 represents the variable cost associated with underutilized storage.

$$VC_7 = \frac{f_{14}}{100} \left\langle \frac{V_d P_{gs}}{V_t} \right\rangle \tag{17}$$

where:

f_{14} = incremental fraction of storage not utilized,

V_t = volume of grain tested per year,

P_{gs} = annual opportunity cost of storage volume, and

V_d = total elevator storage volume.

Misgrades and erroneous data entry will cause errors in the segregation process. Those errors may dilute the average quality of the differentiated grain, which would reduce the premium that could be received at resale. The elevator could pay excess premiums to producers. This cost will be estimated as the opportunity cost of lost premiums, which may or may not be a cash cost depending on how the producer was paid. The cost is estimated as the fraction of misgrades multiplied by the average pricing error caused by the misgrades. In Equation 18, VC_8 is the variable cost of misgrades.

$$VC_8 = \frac{P_{ge}}{100} \Delta P_g \quad \textbf{(18)}$$

where:

P_{ge} = percent of misgrades, and

P_g = premium for quality.

Table B1 presents the input variables used in the elevator-cost model along with the values used for each elevator.

TABLE B1 Variables Used to Estimate Incremental Elevator-Handling Costs of Quality Differentiated Grains

Variable	Symbol	Marshalltown	Liscomb	Rinard	Farnhamville
NIR tester price	P_t	20,000	20,000	20,000	20,000
Price of equipment replaced	$P_{t'}$	3,000	3,000	3,000	3,000
Amortization rate	$(a/p)_n^i$				
Interest rate	i	10	10	10	10
Useful life	n	10	10	10	10
Tester repair cost	p_{rt}	5	5	5	5
Insurance rate	I	10	10	10	10
Income tax rate	t_i	30	30	30	30
Annual depreciation rate	D	10	10	10	10
Grain tested per year (000 bu)	V_t	1,230	1,500	1,322	10,326
Time for testing	t_t	2	2	2	2
Initial testing time	$t_{t'}$	1	1	1	1
Labor cost	P_L	10	10	10	10
Bushels per test	B	400	400	400	400
Price of data handling equipment	P_d'	10,000	10,000	10,000	10,000
Repair of data handling equipment	p_{rd}	5	5	5	5

Modification for sample storage	P_{ss}	2,000	2,000	2,000	2,000
Time spent sorting samples	t_s	1	1	1	1
Accounting Time	t_a	1	1	1	1
Sample check tested by FGIS (%)	f_7	2	2	2	2
Cost of submitted sample grade	P_G	10	10	10	10
Check test accounting time	t_{aG}	5	5	5	5
Software modification costs	PC_s	2,000	2,000	2,000	2,000
Software maintenance costs	p_u	10	10	10	10
Samples disputed by sellers (%)	f_9	5	5	5	5
Value of manager's time	P_{LM}	50	50	50	50
Manager's time spent in disputes	t_m	12	12	12	12
Grain elevation rate	V_b	5,000	5,000	7,500	20,000
Number of segregations	n_s	4	5	4	5

Number of pits	n_p	2	3	2	7
Subjective additional customer waiting time	f_{11}	2	3	3	1
Elevator modification costs	P_m	0	0	0	0
Elevator modification repair costs	P_{rm}	5	5	5	5
Elevator storage volume (000 bu)	V_s	820	1,000	881	6,884
Annual opportunity cost of storage volume	P_{gs}	0	0	0	0
Incremental fraction of storage not utilized	f_{14}	2	2	2	2
Percent of misgrades	P_{ge}	5	5	5	5
Premium for quality	ΔP_q	0	0	0	0
Storage construction costs	P_s	2	2	2	2
Storage and handling facilities repair costs	P_{rs}	5	5	5	5

Property tax rate	t_p	20	20	20	20
Gross elevator margin on generic grain	M	0	0	0	0
Grain handled per year (000 bu)	V_h	1,230	1,500	1,322	10,326

APPENDIX C

Corn processing costs

TABLE C1 Cost Summary for Corn Starch Production from Raw Corn (200,000 BBD)

Cost item	$ 000 per year	Dollars per kg starch	Cents per bushel corn
Raw materials			
Corn	$ 150,541	$ 0.1502	¢ 215.00
Sulfur dioxide	802	0.0008	1.09
Total	151,343	0.1510	216.09
Utilities			
Electricity	5,713	0.0057	8.10
City process water	100	0.0001	0.08
Cooling tower water	1,002	0.0010	1.41
Low pressure steam	3,007	0.0030	4.23
Total	9,822	0.0098	13.82
Labor			
Supervisors	200	0.0002	0.23
Operators	601	0.0006	0.90
Laborers	0	0.0000	0.00
Technicians	100	0.0001	0.20
Total	902	0.0009	1.33
Labor related costs			
Payroll overhead	301	0.0003	0.44
Supervisory and misc.	0	0.0000	0.00
Laboratory charges	0	0.0000	0.00

Total	301	0.0003	0.44

TABLE C1 (Continued)

Cost item	$ 000 per year	Dollars per kg starch	Cents per bushel corn
Capital			
Maintenance	$ 6,715	$ 0.0067	¢ 9.65
Operating supplies	100	0.0001	0.19
Environmental	702	0.0007	0.96
Total	7,517	0.0075	10.80
Capital related costs			
Local taxes	1,303	0.0013	1.93
Insurance	702	0.0007	0.96
Overhead	3,207	0.0032	4.58
Total	5,212	0.0052	7.47
Sales related costs			
Administrative	1,103	0.0011	1.63
Distribution and sales	601	0.0006	0.81
Research and development	601	0.0006	0.81
Total	2,305	0.0023	3.25
Average depreciation costs	3,508	0.0071	10.16
Total non-corn costs	33,977	0.0339	48.36

TABLE C2 Cost Summary for Corn Glucose Production from Starch (200,000 BBD)

Cost item	$ 000 per year	Dollars per kg glucose	Cents per pound starch
Raw materials			
Starch	$ 102.776	$ 0.0970	¢ 4.41
Alpha-amylase	2,649	0.0025	0.11
Gluco-amylase	2,543	0.0024	0.11
Sodium hydroxide	1,271	0.0012	0.05
Calcium hydroxide	0	0.0000	0.00
Sulfuric acid	954	0.0009	0.04
Total	110,193	0.1040	4.72
Utilities			
Electricity	318	0.0003	0.01
City process water	0	0.0000	0.00
Cooling tower water	318	0.0003	0.02
Low pressure steam	2,649	0.0025	0.11
Total	3,285	0.0031	0.14
Labor			
Supervisors	106	0.0001	0.00
Operators	212	0.0002	0.01
Laborers	0	0.0000	0.00
Technicians	212	0.0002	0.01
Total	530	0.0005	0.02

TABLE C2 (Continued)

Cost item	$ 000 per year	Dollars per kg glucose	Cents per pound starch
Labor related costs			
Payroll overhead	$ 212	$ 0.0002	¢ 0.0100
Supervisory and misc.	0	0.0000	0.0000
Laboratory charges	0	0.0000	0.0000
Total	212	0.0002	0.0100
Capital			
Maintenance	4,132	0.0039	0.1800
Operating supplies	106	0.0001	0.0000
Environmental	424	0.0004	0.0200
Total	4,662	0.0044	0.2000
Capital related costs			
Local taxes	848	0.0008	0.0400
Insurance	424	0.0004	0.0200
Overhead	1,907	0.0018	0.0800
Total	3,179	0.0030	0.1400
Sales related costs			
Administrative	1,589	0.0015	0.0700
Distribution and sales	424	0.0004	0.0200
Research and development	1,589	0.0015	0.0700
Total	3,602	0.0034	0.1600
Average depreciation costs	5,933	0.0056	0.2600

Total non-starch costs	17,377	0.0164	1.2400

TABLE C3 Manufacturing Cost Summary for Ethanol Production from Corn Glucose (60 MM GPY Capacity)

Cost item	Dollars per gallon ethanol	Cents per pound glucose
Raw materials	$ 0.9500	¢ 7.4100
Utilities	0.1500	1.1700
Labor	0.0750	0.5900
Labor related costs	0.0250	0.2000
Capital	0.1360	1.0600
Capital related costs	0.0940	0.7400
Sales related costs	0.1330	1.0400
Depreciation	0.2170	1.6900
Total	1.7800	13.9000

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