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Valuing quality differentiated grains from a total logistics perspective

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Valuing quality differentiated grains from a total logistics perspective

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I. 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. To a cattle feeder, a high quality corn would be high in protein, promoting maximum healthy weight gain. To a corn wet-miller, a high quality corn would yield a large quantity of starch. Consequently, high quality corn for cattle feed would be considered low quality to the wet miller.

Both output quality and output yields from different processing techniques vary with specific attribute levels of the raw grain processed. Moreover, a processed output sold in many different markets may encounter different grading criteria depending upon the market in which it is sold. Often, the criteria for determining output premiums and discounts can be related back to the attributes of the raw grain itself. 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).

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

The second component of grain quality has to do with its intrinsic attributes. While these attributes cannot be detected by sight, smell, or touch, they are crucial in determining the quality of the grain as they are directly related the end-use properties of the grain. Some intrinsic attributes are protein, oil, and starch content.

Grain inspection and grading practices

The first grain quality standards in the U.S. were established for wheat in 1856 by the Chicago Board of Trade (CBOT), shortly after its formation (Hill, 1983; CBOT, 1982). Grades for corn, oats and barley were added in the following year. The CBOT also established a department to perform grain grading and appointed grain inspectors in Chicago and Milwaukee in 1858. Exchanges in other cities quickly followed Chicago's lead in developing grain standards and establishing inspection points. Between 1858 and 1865, grades were adopted and inspectors were appointed in Detroit, St. Louis, Cleveland, and Toledo (Hill, 1983). In 1881, the New Orleans Board of Trade adopted similar grain grading and inspection practices.

To provide more uniformity in the system, individual states developed grading and inspection regulations based on physical and sanitary attributes. Illinois was the first to provide inspection under the control of the Railroad and Warehouses Commission in 1871. Minnesota followed suit in 1885, as did several other states soon after. However, since each state adopted its own grades and terminology, there was much confusion and dissatisfaction created among producers and the system soon failed (Hill, 1983).

In 1916, Congress enacted the United States Grades and Standards Act (USGSA). Its purpose was to promote an emerging grain producing industry by providing a uniform and descriptive system to facilitate the long distance trading of grain. As the USGSA evolved, it created the Federal Grain Inspection Service (FGIS) to establish a uniform set of physical and sanitary grades and standards for U.S. grains. In addition, it was responsible for implementing nationwide procedure to provide accurate and unbiased test results on grain.

USGSA still provides grain grades and standards for wheat, corn, barley, oats, rye, sorghum, flaxseed, soybeans, triticale, sunflower seed, and mixed grains (U.S. Congress, 1989). These standards consist of numerical grades 1, 2, 3, 4, and sample grade, each with a list of factors (attributes) and corresponding maximum factor limits. Factors used in grading include moisture content, test weight, percent of damaged kernels and percent of foreign materials. A grade for any lot of grain is based on the results from inspection. The reasons for grading and categorizing grain according to these factors are the same today as they were

150 years ago. Grain which receives a high grade will store and transport with less deterioration (U.S. Congress). Categorizing grain with uniform physical attributes also produces fungible lots of grain which are more easily merchandised.

Shortcomings of USGSA grades and standards

During the late 1970s and 1980s, USGSA grades and standards came under scrutiny. Many of the criticisms highlighted during that period are still unresolved. Critics argue that the grades and standards developed almost 80 years ago have not kept pace with changing world markets and are often misunderstood by foreign importers (U.S. Congress, 1989). Specifically, they claim that U.S. grain grading standards allow producers to ignore factors of economic relevance to the end-users purchasing grain and processed products. Technical innovations in processing and greater sophistication in human and animal nutrition have made grain purchasers keenly aware of the quality factors, both soundness and intrinsic, that affect their output and profitability. The grading and testing system continues to ignore important intrinsic quality attributes like protein, oil, starch, and amino acid content. Critics argue not accounting for intrinsic quality attributes has had an adverse affect on system output, efficiency, and welfare.

Specific limitations cited against USGSA grain standards (U.S. Congress, 1989) are that they:

1. create incentives for practices inconsistent with good management and efficiency,
2. fail to identify many of the attributes related to value in use,

3. fail to reward producers and handlers for improved drying, harvesting, handling, and variety selection, and
4. include arbitrary factor limitations, sometimes not reflecting real differences in value, and, in some instances, not consistent with statistical principles.

USGSA grades and standards have also been under pressure from international markets. By 1986, the U.S. export and net trade position declined to early 1970 levels. A contributing factor to the decline in U.S. exports was grain quality and its use as a competitive tool in international markets (U.S. Congress, 1989; Mercier and Gohlke, 1995). Importing end-users began to understand that grain from the U.S. is of different quality than from other countries. For example, soybeans from Brazil and Argentina typically have a higher protein content than U.S. soybeans (Steimel, 1990). Consequently, when South American soybeans entered the world market, U.S. exports were stifled until the supply of South American soybeans were depleted. Only then did foreign end-users resume purchasing large quantities of U.S. soybeans. (Mercier and Gohlke, 1995)

The competitive situation facing grain producers in Iowa and the Midwest has disturbing parallels to the problems that jolted Detroit automakers in the 1980s (Steimel, 1990). After years of competing on price alone, foreign car companies began to surpass the quality of American-made automobiles. This resulted in a steady and seemingly permanent decline in the Detroit market share. Like the Detroit automakers, U.S. grain producers have fallen behind in the quality race. The grain industry now wonders if it is destined to face the same fate as the automobile, steel, and semiconductor industries.

To improve the quality of U.S. grains, Congress passed the Grain Quality

Improvement Act (GQIA) of 1986 (U.S. Congress, 1989). The Act revised the USGSA to define the purpose of Grades and Standards as:

1. to determine uniform and accepted descriptive terms to facilitate trade,
2. to provide information to aid in determining grain storability,
3. to offer end users the best possible information from which to determine end product yield and quality,
4. to create the tools for the market to establish quality improvement incentives.

Items 1 and 2 of GQIA are not substantially different than the grading criteria established under USGSA. Items 3 and 4, however, were the first attempt to establish grades based on sound economic principles that were absent in the legislative and administrative changes in grades occurring between 1916 and 1986. Although the current grades and standards do not yet reflect many of changes called for in the Grain Quality Improvement Act of 1986, it's clear from this amendment that grain quality has become a policy goal that the United States will be targeting throughout the 1990s and the coming decade.

Advances in biotechnology

One vehicle for improving the quality of U.S. grains is varietal improvement through biotechnology. The branch of biotechnology concerned with quantifiable plant traits, or attributes, is known as quantitative genetics (Falconer, 1960). Quantifiable traits refer to those traits which are measurable, exhibiting continuous or nearly continuous variation. Examples of quantifiable traits in plants include protein, oil, and starch content and kernel hardness. The goal of plant breeders is to improve the productivity of the plant through the application of the principles of modern quantitative genetics to the breeding of plants (Melton, 1979). Organizations funded by U.S. grain producers have expressed great interest in biotechnical research projects in the hopes that they will generate greater returns to grain producers (McVey, Pautsch, and Baumel, 1994).

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. Conventional breeding practices now take 5 to 7 years to breed a specific trait into a variety. Much of this time is taken up in testing cultivars under farm conditions and in seed development. These are steps which must be taken regardless of how a cultivar is produced initially. However, the time from identification of beneficial genes to new plant introduction may be reduced by 4 to 6 years. 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. From a production standpoint, this type of "cafeteria genetics" has tremendous potential to provide specialty grains for individual end-users.

Quality is more than just changing the grades and standards

If the U.S. does not move toward a quality differentiated grain system, the intrinsic quality of grain will continue to lack uniformity across states, regions, and shipments (U.S.

Congress, 1989). The current system will be called upon to inadequately measure intrinsic quality of grain moving within the system. The lack of information on intrinsic qualities will continue to foster inefficiencies in the market (U.S. Congress, 1989).

The issues relating to grain quality, however, run much deeper than simply changing the grades and standards to include criteria for intrinsic quality attributes. Grain is vulnerable to quality deterioration at every link in the distribution channel. Figure 1 shows the many possible routes for grain moving from producer to final destination (U.S. Congress, 1989). We must increase our understanding of the interrelationships among developing varieties of grain, producing, harvesting, storing, handling, testing, and distributing grain (U.S. Congress, 1989).

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 grains differentiated according to both soundness and intrinsic attributes (quality differentiated system) will place great stress on the current system which categorizes grain according to soundness alone (commodity oriented system). Some of the efficiencies which currently ensure low prices for consumers and higher prices for producers via lower marketing margins may have to be sacrificed. Less realistic and more extreme, some believe that the current grain distribution system will not persist unless it meets the consumers' needs and desires as defined by grain quality, availability, and price (Bolen, 1995). Some foresee a process where consumers' needs and desires are fed back into a production and distribution system in order to improve desired quality, availability, and price.

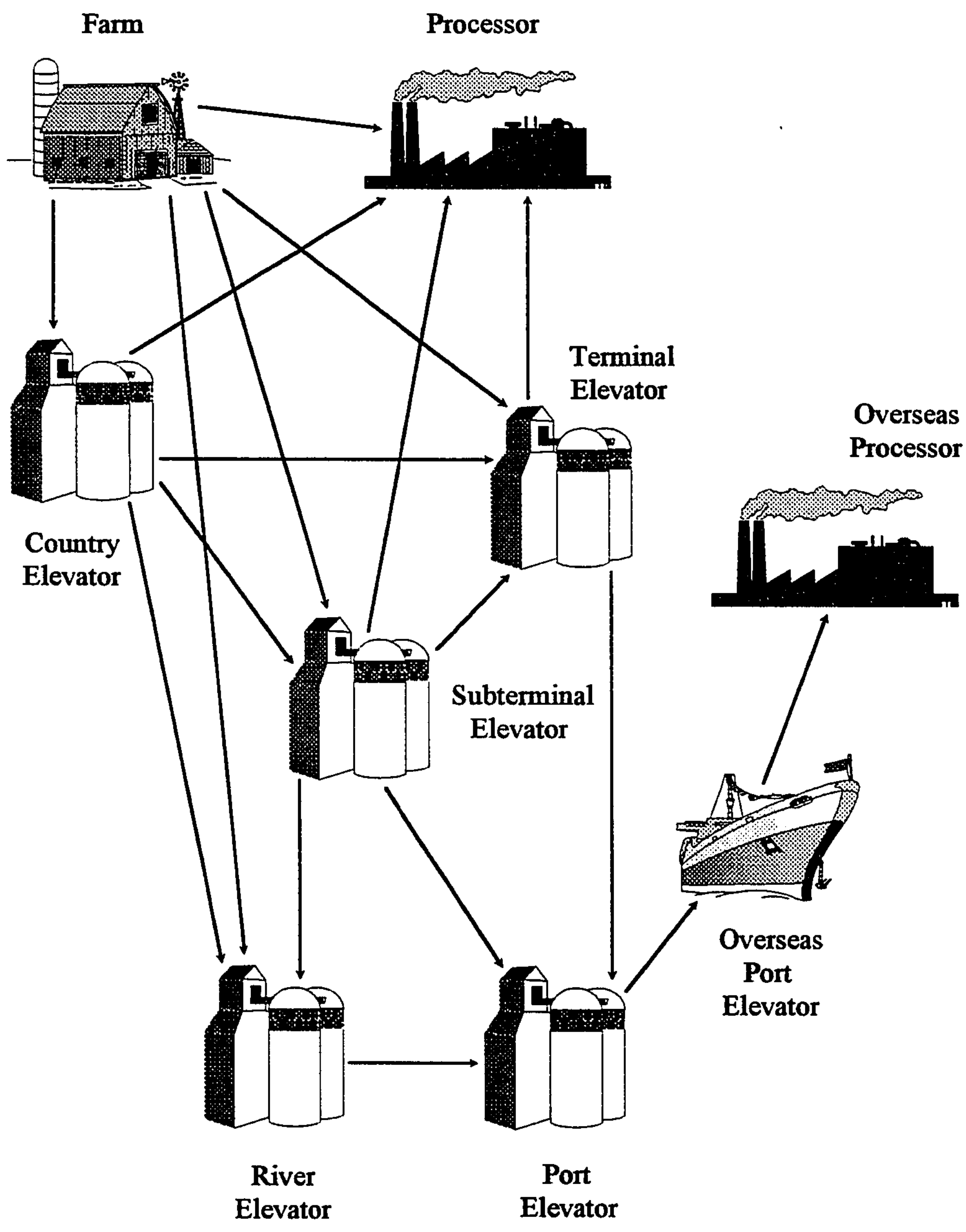

Figure 1. Grain flows from farm to final destination.

Such a process leads to a management system calling for integration at each step in the economic process (Bolen, 1995). This type of a system often results in small quantities of grain being contracted for by processors or elevators, where the buyer has ultimate control over variety choice, production, certification, and delivery.

A fundamental principle of the U.S. grain marketing system has been self-selection. Producers, handlers, and end-users all act in their own perceived best interests (U.S. Congress, 1989). Producers make agronomic decisions with the objective maximizing their own profits; handlers assemble, condition, and deliver grain subject to negotiated contract terms with the objective of maximizing handler profits; and, end-users select among different qualities of grain available, each with different end-use attributes with the objective of maximizing end-user profits or utility. In a quality differentiated system, companies may begin to integrate the various steps of the production system to make sure that the system delivers the desired products at a competitive price. Considerable interest has been expressed by several food, feed, seed, and industrial companies in a distribution system more responsive to their specific needs (Bolen, 1995). Many prefer a system that begins with genetically enhanced seeds and ends with a production and delivery system that keeps the grain identity preserved until delivered to the end-user (Bolen, 1995).

Many systems such as those described are beginning to evolve on a small scale. For example, Pioneer Hi-Bred International has developed a strategic alliance with Kraft Food Ingredients to market specialty vegetable oils (Bolen, 1995). Experts from Quaker Oats Company note a similar trend of food companies partnering with key suppliers (Roskens, 1995). Suppliers are being pulled deeper into the processors' businesses in order to reduce waste, improve efficiencies, and reduce costs. Such strategic alliances may become commonplace within the food chain as participants strive to cut costs and deliver greater value through the system.

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 grains with different intrinsic attribute levels, placing great pressure on the current distribution system. Forcing the current distribution system to handle quality differentiated grains may have a significant impact on producers, elevators, and processors 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 dissertation 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 focussed primarily on the processed value of the grain. Over time, it has become abundantly clear that the logistical costs of identity preservation will also play a significant role in valuing grains of different qualities. Not accounting for the logistical costs of identity preservation which must accompany differentiated grains in order to reap the processing gains, has probably resulted in overestimation of the values of grains of different qualities. It is important to note that the goal of this dissertation 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 likely happen.

Given that the logistical costs of a quality differentiated system play an important role in determining the values of different qualities of grain, it is seems reasonable that grain producers located close to a processor or end-users will produce the qualities of grain desired by these processors or end-users. In other words, the grain production may become localized by quality around quality markets. This study will thus examine the impacts a quality differentiated system will have on the localization of grain production.

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 would allow 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 dissertation 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 paper will track shifts in the modes of transportation from elevator to processor.

After segregating grain by intrinsic qualities at a cost, many grain merchandisers are afraid that they will not be able to resell the grain in a premium quality market and will be forced to sell the grain in the lower priced generic grain market. Consequently, the elevator may face a significant opportunity cost of segregating grain. Another purpose of this paper is to estimate the opportunity cost of segregating grain by quality and not being able to resell it in the quality market.

The final purpose of this paper 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.

II. LITERATURE REVIEW

While the economics literature regarding the impacts of shifting from a commodity based distribution system to a quality differentiated system is limited, that pertaining to biotechnology has attempted to deal with the problem of determining the potential impacts of biotechnology on agriculture (Kalter and Tauer, 1987; Hueth and Just, 1987; Stallman and Schmid, 1987). Many of the issues dealt with regarding biotechnology are relevant to the issue of a quality differentiated system, such as valuing different qualities of grain. Norton and Davis (1981) provide a comprehensive survey of economic studies evaluating the returns to agricultural research up to 1981.

Demand increasing modifications

Traditional consumer and producer surplus models have been used to examine the impacts on consumers and producers from quality enhancements in livestock which increase the demand for livestock products (Wohlgenant, 1993; Brester et al., 1993; Voon and Edwards, 1991a; and Lemieux and Wohlgenant, 1989). Relatively few studies have attempted to quantify the potential domestic welfare impacts from genetically modifying grains and oilseeds to better fit the needs of end-users. Voon and Edwards (1992) examined the research benefits resulting from increasing the protein content in Australian wheat. Similarly, McVey et al. (1994) examined the research benefits accruing to producers and end-users from five different soybean modifications. Both studies indicated significant welfare gains to producers from industry wide quality improvements, provided production costs increase relatively little or that yields are relatively unaffected.

One reason for the limited number of quantitative analyses on demand increasing innovations in grains and oilseeds stems from a lack of data. Much of the information required for economic analysis of new products is based on the performance of products in development. However, in the case of grains and oilseeds, most of the products being considered have not yet been developed. This presents a serious challenge to agricultural economists who rely almost exclusively on ex post or survey data to drive their models (Fishel, 1987). Due to the lack of data, economists' must expand their acceptance of "soft data" (perceptions of scientists on the frontier of biotechnology science).

Figure 2 presents a graphical depiction of the type of analyses typically conducted on demand enhancing modifications. Figure 2 presents a partial equilibrium trade model in which domestic producer and consumer surplus are used to estimate the expected benefits to domestic grain producers and end-users (Willig, 1976). In figure 2, D_{dd} represents domestic demand for grain. The total demand for U.S. grain is represented by D_{td}. Foreign demand for U.S. grain is defined as the difference between total demand and domestic demand. Q_s is the quantity of soybeans supplied by the U.S.

Demand for soybeans is assumed to increase if genetically modified soybeans better meet the needs of end-users. The increase in demand is denoted by a per unit shift in D_{dd} and D_{td}. Domestic demand and foreign demand are both assumed to shift, but not necessarily by the same amount. The added value per bushel to domestic end-users is denoted by v. The marginal added value to producers is given by w. Given that modifications may lead to increased production costs, supply may shift vertically by x.

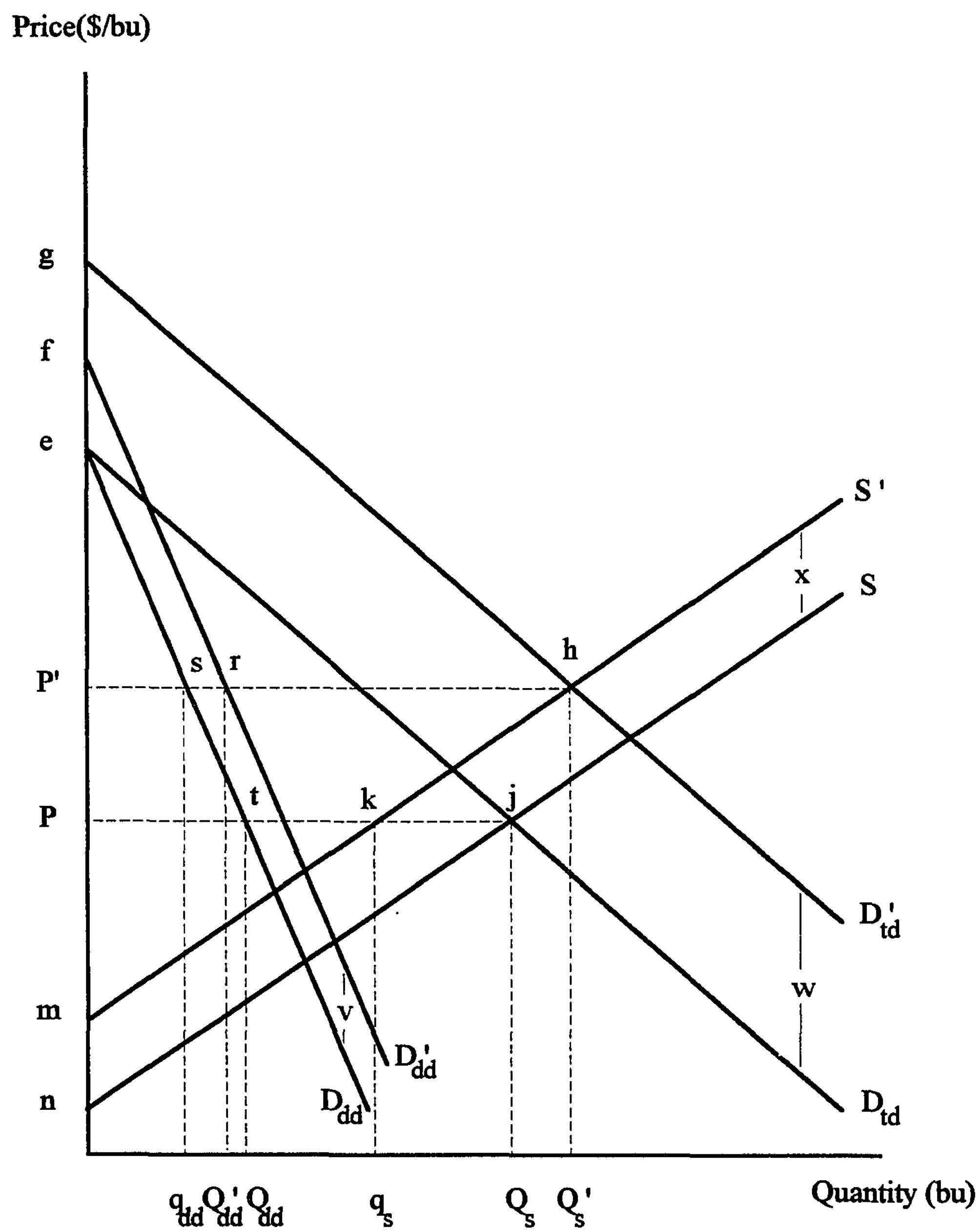

Figure 2. Welfare gains from grain quality improvements.

In figure 2, the annual net benefits to producers from quality improvement is given by the change in producer surplus, which is equal to area P'hm minus area Pjn. Similarly, the annual net benefit to domestic end-users is given by the change in consumer surplus denoted as area P'rf minus area Pte. Discounting the annual benefits less the annual costs of the research to develop the modifications then provides an indication of whether it is advantageous to pursue such quality enhancements.

Supply increasing modifications

Research into the benefits resulting from supply shifting technological innovations have received considerably more attention (Griliches, 1958; Chang, Eddleman and McCarl, 1991; Scobie, Mullen, and Alston, 1991; Mullen, Alston, and Wohlgenant, 1989; Edwards and Freebairn, 1984; Akino and Hayami, 1975; Brennan, Godyn, and Johnston, 1989; and Ayer and Schuh, 1972). Recent works have been spurred on by biotechnical breakthroughs such as porcine somatotropin (PST), a growth hormone in the pork industry. PST adoption was shown to generate significant expected benefits to producers, using even the most conservative predictions of the impacts of PST (Lemieux and Wohlgenant, 1989). Finally, there has been considerable attention focussing on the size of research benefits corresponding to the shape of supply and demand curves (Voon and Edwards, 1991b) and the type of supply shift (Lindner and Jarret, 1978 and 1980; Miller, Rosenblatt, and Hushak, 1988; and Rose, 1980). These analyses are usually conducted as presented in figure 2, setting $v = w = 0$ and setting $x < 0$.

Component pricing

Perrin (1980) determines the effects of pricing products based on the components of the product itself. He examines pricing soybeans based on protein and oil content and pricing milk based on fat content and solids-not-fat. Results of the study suggest potential social surplus gains from changing to component pricing of these commodities are small (less than two percent of commodity value, before deducting the extra costs of such a pricing system).

While the previous studies indicate potential benefits from knowing the attributes embodied in raw grain, the studies are narrow in focus. All of the studies mentioned assume a homogeneous product both before and after modification. However, the essence of the grain quality issue is heterogeneity among grain qualities. It is not likely that all grain producers will produce and supply the same grain quality. Moreover, processors and end-users desire heterogeneous commodities to meed the differing needs of heterogeneous end-users. Different processors and end-users have different quality requirements, and it is unreasonable to think that only one type of quality will serve the needs of all end-users. It's plausible that a differentiated system of some form will evolve in which grains of unique quality are not commingled (kept separate) with other grains of different quality.

Moving to a quality differentiated system has two major implications for the models previously discussed. First, the previous models have no theoretically consistent way to incorporate the substitution effects from producing and processing differentiated quality grains. Second, from a logistics perspective, the value of commodity must include the logistics costs of a quality differentiated system if it is to be considered a credible approximation of the value of the commodity. These cited models fail in both these respects. Consequently, an alternative modeling framework is needed to address these shortcomings.

Input characteristic models

While traditional economic theory allows us to determine the effects of different preferences on demand and the effects of different technologies on input demand and output supply, it does not allow us to determine the effect of changes in the physical qualities of goods on demand and supply (Lancaster, 1971). Traditional analyses provide no insights into how demand will be affected by a specific changes in attribute levels within a good; nor how a new good will fit into consumer preference orderings over existing goods or the existing production technology. Any change in the attribute levels of a good means we must disregard information derived from observing behavior ex-ante (Lancaster, 1971).

Product attributes are the basic concept in input characteristic models (ICM) and the product is simply a collection of attributes. This runs counter to traditional economics where the product is the basic model concept. The earliest study on product attributes was made by Waugh (1928). Waugh collected information on the wholesale prices and attributes of individual lots of asparagus, tomatoes, and cucumbers in the Boston wholesale market. For each lot, he computed the ratio of the price of that lot to the average price of all lots sold. By regressing this ratio on measures of product attributes, Waugh was able to construct average prices of the attributes even though the traders themselves may not know these values.

In the early 1940s, Hazel(1943) observed that when selecting for simultaneous improvement of traits in cattle, it is appropriate to weight each trait by its economic value. Hazel defined the economic value of a trait as the expected increase in profit resulting from each unit of improvement in that trait. Hazel's observation is still relevant today. Breeders and biotechnical engineers are still trying to answer questions such as: What is a better seed worth? What makes one seed worth more? What makes one seed worth more than another? etc. However, since attributes are not sold individually, data regarding the economic values of potentially important attributes are limited.

ICMs provide a framework for deriving the economic values of attributes. The underlying relationships and development of ICMs were formalized in a series of papers in the late 1970s (Ladd, 1978; Ladd and Gibson, 1978; Ladd and Martin, 1976; Ladd and Melton, 1979; Ladd and Suvannunt, 1976; and Melton, Heady, and Willham, 1979). ICMs have been classified as (I) neoclassical production models relying on regression estimation of a production function, or (ii) blending models amenable to analysis by linear or other mathematical programming methods (Melton, Colette, and Willham, 1994). Ladd (1978) outlines the model specifications for each type of model.

Ladd and Martin (1976) used a neoclassical ICM model for input attributes to develop the concept that the purchase price paid for an input should be equal to a linear combination of the attribute yields weighted by the attributes marginal implicit price. They also developed the concept that input demands depend on each input's attributes yields. Ladd and Suvannunt (1976) extended the neoclassical ICM model to consumer goods. In this case, the retail price paid for a good is equal to a linear combination of the attribute yields weighted by their marginal implicit prices. Consumer demand for a product is a function of income, product prices, and product attribute yields. The hedonic modeling performed in the consumer demand literature can be categorized as neoclassical ICMs (Epple, 1987; Hendler, 1975; Jones, 1988; Lancaster, 1966a, 1966b, 1971, and 1975; Lucas, 1974; Rosen, 1975; Trajtenberg, 1989).

The neoclassical ICM model is defined as follows. Considering a competitive firm, assume the production function for a firm is $Q=f(x_{1.},x_{2.},\ldots,x_{m.})$, where $x_{j.}$ is the total amount of attribute j used in production. The firm's problem is defined as,

$$\max_{v} \; PQ - \sum_{i} R_i v_i \tag{1}$$

subject to,

$$x_{j.} = \sum_{i} x_{ji} \, v_i \qquad \forall j \; . \tag{2}$$

$$Q = f(x_{1.}\,,\, x_{2.}\,,\, \ldots,\, x_{m.}) \quad , \tag{3}$$

where,

v_i = quantity of the ith input used in production,

R_i = fixed price of the ith input,

P = fixed price of output,

Q = quantity of output produced,

x_{ji} = quantity of attribute j provided by one unit of input I used in production.

Manipulating the first order conditions for profit maximization yields,

$$R_i = p \sum_{j} \left(\frac{\partial f}{\partial x_{j.}} \right) x_{ji} \qquad i = 1, \ldots, n \quad , \tag{4}$$

where the value of an input is equated to the sum of the value marginal products of the input's n attributes weighted by the input's marginal contribution of the attributes.

Simplifying yields,

$$R_i = \sum_j r_j * x_{ji} \quad , \tag{5}$$

where,

r_j = value marginal product of the jth attribute, $p(\partial f/\partial x_{j.})$, (ie. value of the jth attribute),

x_{ji} = level of the jth attribute in the ith input, $\partial x_{j.}/\partial v_i$.

Regressing R_I on the attribute levels of the ith input allows for the direct estimation of the value of the input's embodied attributes.

Building on the work of Ladd and Suvannunt, Unnevehr (1986) examined the benefits from improving the quality of southeast Asian rice. Unnevehr used the implicit prices of rice attributes to evaluate the rice-breeding goals southeast Asia and estimated the returns to research for quality improvement. Similarly, Unnevehr and Bard (1993) applied Ladd and Suvannunt's model to beef quality. Using the implicit prices for beef attributes Unnevehr and Bard concluded that consumers consistently place a negative value on external fat for all table cuts of beef and on seam fat in chuck and round cuts of beef, but do not consistently value intramuscular fat. They also concluded that these consumer preferences are not transmitted to cattle feeders through price signals, even though the current beef grading system can distinguish carcasses with undesirable fat attributes.

Ladd and Gibson (1978) applied a blending formulation to swine production to consider the value of genetic attributes (average daily weight gain, feed efficiency, and back-fat depth) and genetic technological change where the attributes may effect returns, technical coefficients relating input use per unit product, or both. Ladd and Gibson (1978) define economic value as: "The amount by which maximum profit may be expected to increase for each unit of improvement in the trait in each animal" (p.237).

The blending problem is set up as follows. Assume the traits of all biological inputs and outputs are known, prices are fixed, and producer is a profit maximizer. The producer problem can be written as a linear program in which x_j is the level of the jth activity, c_j is the net return per unit of the jth activity, b_I is the total amount of the ith fixed resource, a_{ij} is the amount of the ith fixed resource used in production of one unit of output by activity j. The problem is to maximize total profit Z, where $Z = \Sigma_j c_j x_j$ subject to the resource constraints $\Sigma_i a_{ij} * x_j \leq b_i$. Assuming Z_0 and x_{j0} are the optimal solution values for Z and x_j, the economic value of the hth trait is $EVal_h = (dZ_0/dg_h)/n_{h0}$, where g_h is the level of the hth trait, and n_{h0} is the level of the commodity undergoing a change in attributes.

On the down side, neoclassical ICMs require estimation of a production function by regressing output on a large number of unobserved genetic attributes. In most cases, the required data are not available, especially for undeveloped attributes. Blending ICMs require individual attributes to be treated as independently available inputs. The causal relationships between each attribute and the product of the model also need to be fully specified. For genetic attributes in variety choices, neither data requirement is especially true nor satisfying. Consequently, neither neoclassical nor blending ICMs are fully applicable when estimating the economic values of genetic attributes. This is especially true for inseparable bundles of genetic attributes such as the variety choice decision of grain producers (Melton, Colette, and Willham, 1994). However, by modifying these two methods, Melton, Colette, and Willham (1994) were able to provide an extended ICM to produce a more suitable alternative. The model presented in the next section relies heavily on the model established by Melton, Colette, and Willham (1994), extending it to account specifically for the logistical aspects of the grain quality issue.

III. MODEL

An extended input characteristic model (ICM) 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 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 sells the processed grain products and/or feeds the meal and raw feed grains to livestock [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 including selecting a seed stock in the form of an inseparable bundle of attributes. Often these attributes are unobservable and inseparable. For example, it is impossible to increase protein content in soybeans without sacrificing the oil producing capabilities of the plant. An aggregate genotype for a single acre of land in grain production is used to represent the genetic basis for distinguishing one grain variety from another. Soundness attributes for each variety modeled are assumed to comply with specifications outlined for No. 2 grade grain. Consequently, varieties are distinguished by their genetic differences only. Assuming each acre of production is composed of p attributes, the genomic value for an acre of grain production of the jth variety of grain in terms of its embodied attributes is given by equation 6,

$$G_j = g(q_{j1}, q_{j2}, \ldots, q_{jp}) \quad , \tag{6}$$

where,

G_j = aggregate genotype for one acre of production of grain variety j,

q_{ji} = level of the ith attribute embodied in one bushel of grain variety j.

In keeping with common practices in plant breeding, the kth attribute's contribution to the jth genomic value is a constant, α_k, implying,

$$\frac{\partial G_j}{\partial q_{jk}} = \alpha_k \quad . \tag{7}$$

This assumption implies that G_j may be written as,

$$G_j = \sum_k \alpha_k q_{jk} \quad . \tag{8}$$

It is obvious that equation 8 is homogeneous of degree one. Intuitively, equation 8 states that a bushel of grain is simply the sum of its embodied attributes; and if the level of all attributes is doubled, it is equivalent to having two identical bushels of grain (Lancaster, 1971).

Given equation 8, the total genomic value of the crop planted by the firm, G, can now be defined as in equation 9,

$$G = \sum_j G_j * A_j \quad , \tag{9}$$

where,

A_j = number acres of land in production of the jth variety grain.

Equation 9 states, that if a single acre of land could produce grain which possessed the same attributes as the entire crop currently in production, its genomic value would be G. The intuition behind equations 8 and 9 is crucial to the development of the model.

Given G and the fact that most agricultural commodities are processed into more than one output (soybeans into meal and oil, corn into ethanol and corn gluten feed), the firm's multioutput production technology is expressed as,

$$T(y_1, y_2, \dots, y_m, x_1, x_2, \dots, x_n, t_1, t_2, \dots, t_w; G) = 0 \quad , \qquad (10)$$

where,

T = transformation function transforming inputs into outputs

y_i = level of the ith output produced (meal, oil, meat, hides, etc.),

x_k = level of the kth (non-genetic) input used production and processing (labor, capital, etc.),

t_l = level of the lth logistical input used (transportation, purchasing, inventory, etc.)

Thus, the firm maximizes system profits under fixed prices,

$$\max_{y,x,t} \ \pi = \sum_i p_i y_i - \sum_k w_k x_k - \sum_l r_l t_l - R \qquad (11)$$

subject to

$$T(x,y,t,A;G) = 0 \quad ,$$

$$\sum_{j=1}^{v} A_j = A$$

where,

p_i	=	price of the ith output,
w_k	=	price of the kth (non-genetic) input,
r_l	=	price of the lth logistical input,
R	=	fixed costs of production, processing, and logistics,
A	=	total acres in production.

Maximizing equation 11 results in $y_i^* = y_i(p,w,r,A,G)$, $x_i^* = x_i(p,w,r,A,G)$, and $t_i^* = t_i(p,w,r,A,G)$. The indirect profit function can then be expressed as,

$$\pi^* = \sum_i p_i y_i(p,w,r,A,G) - \sum_k w_k x_k(p,w,r,A,G) - \sum_l r_l t_l(p,w,r,A,G) - R \qquad (13)$$

From the indirect profit function, total genomic value of grain in production is defined as partial derivative of profits with respect to the aggregate genotype, G,

$$\frac{\partial \pi^*}{\partial G} = \sum_i p_i \frac{\partial y_i}{\partial G} - \sum_k w_k \frac{\partial x_k}{\partial G} - \sum_l t_l \frac{\partial t_l}{\partial G} = \lambda \quad . \qquad (14)$$

In equation 14, the value of an additional unit of genomic value is equal to the sum of the value marginal products of the output influenced by the added unit of genomic value less the marginal production and logistical costs of a unit of genomic value. Adding another unit of genomic value allows the integrated firm to either increase the production of output or increase the quality of its output as defined by $\partial y_i/\partial G$. While another unit of genomic value increases revenue, it also effects the costs associated with producing and processing grain ($\partial x_k/\partial G$) and transporting and distributing grain ($\partial t_i/\partial G$). Production costs may change for a variety of reasons such as yield reductions, changes in nutrient requirements, pesticide tolerance, etc. Processing costs may change because of changes in ration formulae, changes in processing techniques (eg. eliminate partial hydrogenation in soybeans), etc. Logistical costs may also change for a variety of reasons such as changes in inventory decisions, market shifts, changes in the risk of storing air, etc. The changes in logistics costs are critical in determining whether there is any benefit in shifting from a commodity based system to a quality differentiated system.

Equation 14 does not equate to zero since producers are forced to choose from among a finite number plant varieties. Consequently, given fixed output and non-genetic input prices, the most the firm could afford to pay for a unit increase in genomic value from the jth variety of grain is equal to the sum of the expected change in profits,

$$w_j = \lambda_j \quad , \tag{15}$$

where λ_j, the per unit opportunity cost associated with an acre of production of the jth variety of seed stock, is calculated as $\partial\pi/\partial G_j$.

Since the genomic value of an acre of production of grain variety j, which is actually an index of attributes, is linearly homogeneous, Euler's Theorem implies,

$$G_j = \sum_k \left(\frac{\partial G_j}{\partial q_{jk}} \right) q_{jk} \quad . \tag{16}$$

The value of an acre of production of the jth variety of grain can then be determined as,

$$w_j G_j = \sum_k w_j \left(\frac{\partial G_j}{\partial q_{jk}} \right) q_{jk} \quad . \tag{17}$$

Using equation 7, the economic value of the kth attribute in the jth genomic value can be defined as,

$$w_{jk} = \frac{\partial w_j G_j}{\partial q_{jk}} = w_j \frac{\partial G_j}{\partial q_{jk}} = w_j \alpha_k \quad . \tag{18}$$

Substituting equation 18 into the genomic value of an acre's production of the jth variety grain implies,

$$w_j G_j = \sum_k w_{jk} q_{jk} \quad . \tag{19}$$

Equation 19 implies that the value of a bushel of variety j grain is equal to the sum of the marginal values of its embodied attributes weighted by the attribute levels. This result is consistent with previous neoclassical ICM results; however, in this formulation the value of a variety of grain is not simply the processed value of the grain, because the added logistical costs of identity preservation are also included in w_{jk}.

The relative economic value of an acre's production of variety h grain can also be derived from the indirect profit function. Differentiating with respect to the number of acres allocated to grain variety, A_h, yields,

$$\frac{\partial\pi^*}{\partial A_h} = \sum_i p_i\frac{\partial y_i}{\partial G}\sum_j \frac{\partial G}{\partial A_j}\frac{\partial A_j}{\partial A_h} - \sum_k w_k\frac{\partial x_k}{\partial G}\sum_j \frac{\partial G}{\partial A_j}\frac{\partial A_j}{\partial A_h} - \sum_l r_l\frac{\partial t_l}{\partial G}\sum_j \frac{\partial G}{\partial A_j}\frac{\partial A_j}{\partial A_h} \quad . \tag{21}$$

Rearranging,

$$\frac{\partial\pi^*}{\partial A_h} = \left[\sum_i p_i\frac{\partial y_i}{\partial G} - \sum_k w_k\frac{\partial x_k}{\partial G} - \sum_l r_l\frac{\partial t_l}{\partial G}\right]\sum_j \frac{\partial G}{\partial A_j}\frac{\partial A_j}{\partial A_h} \quad . \tag{22}$$

Combining terms,

$$\frac{\partial\pi^*}{\partial A_h} = \left[\frac{\partial\pi}{\partial G}\right]\sum_j \frac{\partial G}{\partial A_j}\frac{\partial A_j}{\partial A_h} \quad . \tag{23}$$

Plugging in equation 14 and simplifying,

$$\frac{\partial\pi^*}{\partial A_h} = \lambda \sum_j \frac{\partial G}{\partial A_j}\,\eta_{jh} \quad , \tag{24}$$

where $\eta_{jh} = \partial A_j/\partial A_h$ is the marginal rate of substitution between an acre of land in production of variety j and an acre of land in production of variety h.

Plugging in the definition of $\partial G/\partial A_j = G_j$ implies,

$$\frac{\partial\pi^*}{\partial x_h} = \lambda \sum_j \eta_{jh} \sum_k \alpha_k q_{jk} \quad . \tag{25}$$

Thus, the marginal economic value of an acre of production of variety h can be estimated as the sum of the differences in attribute values between varieties, adjusted for the marginal rates of substitution.

Dividing equation 24 by the per acre yield of variety h results in the marginal economic value of a bushel of variety h grain being equal to,

$$\mathrm{Eval}_h = \left(\frac{1}{B_h}\right) \lambda \sum_j \eta_{jh} \sum_k \alpha_k q_{jk} \quad . \tag{26}$$

Linear programming problem

The extended ICM problem is now transformed into 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 commercially available varieties in order to maximize the net returns to given resources (land, capital, labor, equipment, etc.) at fixed prices. In this case, each variety of grain included in the model is considered as an alternative genome. A linear programming representation of this problem (similar to a blending ICM) can be stated as,

$$\underset{N}{\mathrm{Max}}\ Z = \sum_{i=1}^{M} c_i N_i + \sum_{j=M+1}^{N} c_j N_j + \sum_{k=M+N+1}^{A} c_k N_k + \sum_{l=M+N+A+1}^{L} c_l N_l + \sum_{m=M+N+A+L+1}^{P} c_m N_m \tag{27}$$

subject to,

$$\sum_{J=1}^{n} a_{IJ} N_J \le b_I \qquad i=1,2,\ldots,m \quad , \tag{28}$$

$$N_J \geq 0 \qquad \forall \ 1 \leq J \leq P \quad . \tag{29}$$

where,

N	=	firm activity,
c	=	net return from activity,
I	=	product marketing activities of the firm,
j	=	grain production activities of the firm,
k	=	livestock production activities of the firm,
l	=	logistics activities of the firm,
m	=	grain processing activities of the firm,
b_I	=	total amount of the Ith resource available to the firm,
a_{IJ}	=	level of Ith resource (b_I) required per unit of the Jth varietal activity.

Denote Z^0 as the optimal objective function value arising from selection of an optimal variety. The marginal economic value of each variety, N_h (M+1<h<N), can be derived for the fixed resource base as,

$$\frac{\Delta Z^0}{\Delta N_h} = \sum_j c_j \frac{\Delta N_j}{\Delta N_h} = z_h - c_h \quad . \tag{30}$$

Equation 29 is equal to the shadow price of an acre of production of the hth 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).

From the extended ICM model, the shadow price of an acre of production, $\Delta Z^o/\Delta N_h$, is,

$$z_h - c_h = \lambda \sum_j \eta_{jh} \sum_k \alpha_k q_{jk} \quad . \tag{31}$$

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, ($\Delta Z^o/\Delta N_h$) 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 hth variety of grain.

These two procedures satisfy the first two purposes of this paper. However, to satisfy the third purpose, we assume that there is no quality differentiation present in the model. In this case, the difference in profits from the first scenario and this scenario is the welfare impact on producers, elevators, and processors from shifting from a commodity based grain distribution system to a quality differentiated system. Second, by determining which farms produce which qualities of grain determines the extent of the localization of production. Moreover, by tracing the grain flows in each scenario, we can track how producers and elevators shift among markets and modes.

IV. DATA

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

In contrast, the second study region consisted 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 system should be accurately reflected by the results from these two study areas.

Farm level data

The representative firm was assumed to have one representative farm in each study region. The firm had the opportunity to produce three varieties of corn, three varieties of soybeans, and livestock on each farm. The three varieties of corn have been labeled as wet mill, feed, and generic corn, according to which 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 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 -- 1.5 percent more protein than generic corn and 4.85 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, in percents.

	Corn variety		
Attribute	Wet Mill	Feed	Generic
Crude protein	5.15 %	10.00 %	8.50 %
Crude oil	3.60	3.60	3.60
Starch	63.00	58.50	60.00
Lysine	0.90	0.90	0.90
Methionine	0.70	0.70	0.70

Similarly, the firm had a choice of producing three varieties of soybeans -- high protein soybeans, high oil soybeans, and generic soybeans. Table 2 lists the attribute levels for three varieties of soybeans (Brumm and Hurburgh, 1990). The variety of soybeans high in protein has a crude protein level of 38 percent and a crude oil level of 16.6 percent. The high oil variety of soybeans has a crude protein content of only 31.6 percent, while the crude oil

Table 2. Soybean attribute levels, based on 13 percent moisture.

	Soybean variety		
Attribute	High protein	High oil	Generic
Crude protein percent	38.00	31.60	35.50
Crude oil percent	16.60	20.10	18.20

content was 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 and oil content of 35.5 percent and 18.2 percent, respectively.

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, but 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 county levels. Yields in Webster and Calhoun counties were simply averaged and assigned to the 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 of 1990 and 1991 are typical production figures for Iowa, however, the years of 1992 and 1993, are not. In 1992, Iowa experienced a superb growing year resulting in a record breaking crop. The year of 1993 was quite the opposite as Iowa's production was stifled as a result of severe flooding. On average these two years nullify each other.

Table 3. Iowa and county corn and soybean yields, in 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
	State wide	42	41	44	30	39

The average yields per acre for corn and soybeans in Marshall County for this time period were 122 bushels per acre and 43 bushels per acre, respectively. These per acre yields were assigned to the farm in Marshall County. The counties of Webster and Calhoun saw corn yields average 130 and 134 bushels per acre, respectively. Soybean yields over this same time period averaged 39 bushels per acre in Webster County and 41 bushels per acre in Calhoun county. The farm in this study region was assigned average corn yields of 132 bushels per acre and average soybean yields 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 thousand acres to 156 thousand acres. Average acres in production over the time period are approximately 150 thousand acres. Soybean acres in Marshall County ranged from 80 thousand acres in 1990 to 89 thousand acres in 1993. Average soybean acres in production over the time period was approximately 84 thousand acres. Based on the averages corn acres are 1.8 times greater than the 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, in 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
	State wide	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
	State wide	8,000	8,700	8,150	8,600	8,363

In Calhoun County, corn acres in production ranged from 150 thousand acres in 1993 to 166 thousand acres in 1992. The average number of acres in production was approximately 157 thousand acres. Soybean acres in Calhoun County ranged from 150 thousand acres in 1990 to 171 thousand acres in 1992. The average number of soybeans acres in production over the same time period was 157 thousand acres. Consequently, the ratio of corn acres to soybean acres is approximately 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 farm in Marshall County, for every of 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 farm in the Webster and Calhoun County region 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

Three livestock feed markets were constructed in the model. Two markets were local feed markets where local grain producers also produce livestock. These two markets were simply the farmer feeding corn to livestock right out of the fields. The third livestock feed market, designed to represent the national market for livestock, was arbitrarily located at St. Louis. This market was intended to capture Iowa grain shipments not exported out of the United States.

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

Table 5. Iowa corn and soybean production costs per acre, in dollars per acre.

Cost item	1990	1991	1992	1993	Average
			Corn following soybeans		
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

were constructed from five livestock classes. Livestock classes included beef-fed, pork-sows, pork-fed, lambs-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).

Nutrient requirements for the three different grain consuming units were estimated by first multiplying each livestock class' average daily nutrient requirements by the number of head in the livestock class in each market. This step yields the average daily nutrient requirements for 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 animals in each market and multiplying by 365 days, yields the average annual nutrient requirement for one grain consuming unit. The total number of grain consuming animals 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 had a livestock capacity of 1,159 grain consuming units and the farm in Webster-Calhoun 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 livestock were estimated is presented in Appendix A.

Table 6. Annual nutrient requirements for one grain consuming unit, by livestock feed market.

	Livestock market		
Nutrient	Marshall	Webster - Calhoun	St. Louis
Dry matter (lbs)	1,450.61	1,346.93	3,627.81
Metabolizable energy (Mcal)	1,890.32	1,779.41	4,214.16
Protein (lbs)	172.29	162.40	385.13
Amino acids			
Lysine (lbs)	6.64	6.77	3.81
Methionine (lbs)	3.66	3.73	2.10

Each livestock market was allowed to formulate feed rations from the three varieties of corn and processed feed supplements to satisfy livestock nutrient requirements. 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 corn provides the most metabolizable energy and the feed variety 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.

Four processed outputs were included as possible feed supplements, including corn gluten feed and 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

Table 7. Metabolizable energy provided by each variety of corn by livestock market, on an as fed basis in Mcal/lb .

	Corn variety		
Livestock market	Wet Mill	Feed	Generic
Marshall County	1.585	1.506	1.532
Webster-Calhoun	1.590	1.510	1.537
St. Louis	1.468	1.408	1.427

were produced from each of the three varieties of corn. In all likelihood, the nutrient content of the glutens varies according to which corn it was produced from. However, since no data are available to quantify the differences, the corn gluten nutrient shares were assumed constant across corn varieties. The two soybean meals are outputs from the soybean processing. All are high quality feed supplements. The final feed supplement allowed in the ration formulation was corn silage. Corn silage was assumed 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 nutrient shares provided by corn silage were assumed to be constant 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	.78	2.9	3.12	0.64
Methionine percent	0.4	1.07	.52	.71	0.66
Metabolizable energy (Mcal/lb)					
Marshall County	1.421	1.883	1.412	1.488	0.034
Webster/Calhoun	1.424	1.895	1.416	1.491	0.026
St. Louis	1.360	1.631	1.340	1.402	0.191

The cost of feeding the different feed ingredients varied by the 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 for blending 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 $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 $1,120.43 per head on 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 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, and in the St. Louis market the cost was $284.34 per grain consuming unit.

Livestock prices

Prices received for livestock were constructed similar to livestock production costs. Table 10 presents Iowa (Wisner et al., 1995) and U.S. livestock prices (National Agricultural Statistics Service, 1994) received over the period from 1991 to 1994. Income per animal was calculated by multiplying each animals average production by its corresponding commodity price. The annual production per animal was: 1,100 pounds for fed-beef; 152 pounds for pork sows; 250 for fed-pork; 110 pounds for fed lambs; and 12,000 pounds of milk for dairy cows

Table 9. Non-feed production costs for selected livestock classes, in 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	138.60
Boar depreciation		10.00			
Interest, insurance,		11.18			138.60
Total	536.04	221.97	20.81	68.55	1,120.43

Table 10. Average annual commodity prices, in dollars per hundred weight, 1991-1994.

		Livestock class				
Market	Year	Fed-beef	Pork-sows	Fed-Pork	Fed- lamb	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
U.S.	1991	72.70	40.60	49.10	52.20	12.27
	1992	71.30	32.20	41.60	59.50	13.15
	1993	72.60	35.50	45.20	64.40	12.86
	1994	66.70	31.00	39.90	65.60	13.01
	Average	70.83	34.83	43.95	60.43	12.82

(Lawrence et al., 1994). The income from one grain consuming unit was calculated as the weighted average of income per animal, where the weights were the shares each livestock class in production. The income received from one grain consuming unit in Marshall County was $156.26, in Webster and Calhoun counties was $143.14, and in St. Louis was $473.71.

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, which 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 and capacities in 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 cost of handling and merchandising grain in today's market were extracted from Chase, Helgeson, and Shaffer (1983). In their report, Chase, Helgeson, and Shaffer (1983) surveyed 463 elevators in South Dakota on their cost of handling grain. They provide 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, Helgeson, and Shaffer (1983) data based on data provided in Baumel et al. (1991) and Baumel, McVey, and Hurburgh. (1992). These data, however, do not address the incremental costs of segregating intrinsically different grains.

Incremental segregation and handling costs per bushel were estimated using a methodology developed by 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 per bushel grain handling costs 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 and incremental and total costs handling costs for a differentiated market, in cents per bushel.

County	City	Generic handling cost	Differentiated handling costs	
			Incremental	Total
Marshall	Marshalltown	12.20	3.09	15.29
	Liscomb	10.90	3.13	14.03
Webster-Calhoun	Rinard	12.20	2.96	15.16
	Farnhamville	10.90	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 grocery products. Wet milling also produces corn gluten feed and corn gluten meal which are used as high-quality animal feeds. The wet milling industry is the largest non-feed user of corn, using approximately 1 billion bushels annually (Huber et al., 1995).

For the model, a corn processing plant was created and assumed to be located in Cedar Rapids. Currently, Cedar Rapids has three corn processors in operation. Since the per bushel costs 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 location, and average daily throughput (Iowa Corn Growers Association, 1995; Zdrojewski, 1995).

Plant capacities range from 55,000 bushels per day at Penford Products in Cedar Rapids to 410,000 bushels per day at 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 at 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 plant at Cedar Rapids was also assumed to have the capabilities to produce starch glucose, HFCS and ethanol. No one

Table 13. Iowa wet corn millers: plant locations and average daily throughput, in bushels, 1992.

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
Roquett America	Keokuk	120,000
Penford Products Co.	Cedar Rapids	55,000
Average		194,286

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 America	X	X		X	X
Penford Products Co.	X	X			
Number of plants	5	4	1	4	4

processor in Table 14 produces all four products, but the combination of the three processors in Cedar Rapids do produce all four.

The average output of products from a bushel of corn varies by processor due differences in processing techniques and goals. Table 15 presents the average per bushel product yields 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.

The processing yields for each variety of corn are presented in Table 16. It was assumed that 98% 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

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	

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
55% HFCS	pounds dry	36.55	33.93	34.81
Ethanol	gallons	2.85	2.65	2.72

rates. Oil recovery was assumed to be 100%. 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.

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 55% HFCS 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 National Renewable Energy Laboratory -- 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 a dollars per pound of starch, assuming 1:1057 conversion rate of starch to glucose. Table 17 shows the cost of producing starch, glucose, 55% HFCS, and ethanol. For a detailed explanation of the processing cost data, see Appendix C.

Corn glucose is often converted into the popular sweetener HCFC 55%. Descriptive data on the conversion of glucose to HFCS 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 are range from 33 - 37 percent of total costs. Assuming fixed costs represent 33 percent of the total cost of producing 55% HFCS, the total cost of producing one pound of 55% HFCS is 9.7 cents per one pound of glucose. This 9.7 cents, however, includes the starch and glucose production phases also. Subtracting the costs

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
55% HFCS	5.79	/lb glucose
Ethanol	13.90	/lb glucose

of starch and glucose production results in a glucose conversion to 55% HFCS cost of 5.79 cents per pound of glucose, 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 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 MM gallon per year facility was $1.78 per gallon. Using the glucose-ethanol conversion factor, this translates into 13.9 cents per pound glucose.

Soybean processing

Soybean solvent extraction, the component separation of oil and protein-carbohydrate-fiber (meal), is the 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 3 soybean processing firms with plants in Iowa. These three firms own and operate ten 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 which 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. For the model, a plant was constructed at Iowa Falls with a daily crush equal the average, 68,000 bushels per day.

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
	Sgt. 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, 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 48% protein soybean meal was estimated by removing the hulls from the meal, which is approximately 10 percent of the bulk.

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 9 cents per bushel (Fiala, 1995). Hence total processing costs were assumed to be 42 cents per bushel.

Table 19. Soybean processing outputs by soybean variety, in 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

Prices of processed grain products

Table 20 presents a listing 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 55% HFCS 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 4 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	¢/lb	27.50	25.82	20.90	26.38	25.15
Corn gluten meal	$/ton	237.68	265.79	284.60	286.61	268.67
Corn gluten feed	$/ton	97.94	101.49	95.95	88.62	96.00
Corn starch	$/cwt	11.02	11.03	10.70	12.61	11.34
Corn glucose	¢/lb	14.53	16.48	12.50	15.11	14.66
55% HFCS	¢/lb	22.50	23.75	20.60	22.87	22.43
Ethanol	$/gal	-	-	1.13	1.16	1.15
Soybean oil	¢/lb	21.00	19.10	21.40	27.09	22.15
Soybean meal 44%	$/ton	168.60	177.70	180.80	181.82	177.23
Soybean meal 48%	$/ton	181.40	189.20	193.75	192.86	189.30

Export market

For both Marshall and Webster-Calhoun, the export market was assumed to not differentiate grain based upon 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 the optimal route. While these activities are well within the realm of relevant quality issues, they are beyond the scope the of this dissertation.

The export market was introduced into the model by creating a barge terminal at East Clinton, Illinois. This barge facility was assumed capable of handling all grain shipped from elevators within Marshall and Webster-Calhoun. 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 from 1991 to 1994, excluding periods when the river is frozen. The average cash closing bid for corn was $2.38 and for soybeans was $5.94 (United States Department of Agriculture, selected years).

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 the two elevators in the same county were assumed to be equal across counties. When farmers transport their grain from farm to an elevator without rail capabilities they travel an average of

Table 21. One-way miles from farm to elevator.

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

4.5 miles one-way. When farmers transport grain to elevators with rail capabilities the have to travel an average of 11 miles one-way (Baumel et al., forthcoming). Consequently, the farms were positioned accordingly.

To simplify the model, farms were limited to two types of vehicle types -- a tractor pulling two-300 bushel wagons or a semi-tractor trailer capable of hauling 1000 bushels -- for transporting grain from farm to market. 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, 1995), and for tractor-wagons, the cost per mile to transport grain was assumed to be $1.20 (Edwards, 1995). From the commercial transport rates, it is more cost effective to ship grain by semi tractor-trailer rather than by tractor-wagon. Table 22 presents the total round trip cost for shipping grain from farm to elevator by tractor and 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 by 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, in dollars per load.

Vehicle	County	Marshalltown	Liscomb	Rinard	Farnhamville
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 markets, one-way miles.

Farm location	Cedar Rapids	Iowa Falls
Marshall County	68.0	61.5
Webster-Calhoun	166.5	69.5

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

Table 24. Semi grain transport costs from farm to markets.

Farm location	Cedar Rapids	Iowa Falls
Marshall County	$136.00	$123.00
Webster/Calhoun counties	333.00	139.00

was $333.00 to Cedar Rapids and $139.00 to Iowa Falls. Marshall county has a considerable competitive advantage over Webster-Calhoun when shipping corn to the wet-miller in Cedar Rapids. The Marshall County advantage is significantly less in the soybean market.

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

Table 25. One-way miles from elevator to markets.

Origins	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 for a semi load of grain of $1.00 per mile, 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 3500 bushels. The rail rate from Liscomb and Farnhamville to the corn processor in Cedar Rapids is bid as East Clinton (Industry Sources).

Table 26. Commercial transport rates from elevator to markets by vehicle type.

	Semi-truck rate to			Rail rate to		
Origins	Cedar Rapids	East Clinton	Iowa Falls	Cedar Rapids	East Clinton	Iowa Falls
Marshalltown	$136.00	$302.00	$108.00			
Liscomb	166.00	332.00	98.00	$842.80	$842.80	$588.00
Rinard	330.00	502.00	140.00			
Farnhamville	314.00	486.00	140.00	842.80	842.80	627.20

V. RESULTS

Base solution

This solution attempts to mimic the grain industry under the assumption that quality differentiated corn and soybeans were 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 4. 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 was assumed to have 1000 acres of farmable ground. When compared to 1992 *U.S. Census of Agriculture* data, this figure appears large, however, census data on farm size includes small part-time and hobby farmers who use farming to supplement other sources of income.

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 at 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. These figures were estimated by multiplying each farm's share of total county acres multiplied 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; and the farm in Webster-Calhoun composed 0.15 percent of the total acres harvested for grain in the two counties.

Corn exports for the state were also constrained to 33 percent of the production (Baumel et al., 1992). Soybean exports were not constrained in the model, because there are only two potential markets for soybeans -- processing and export. Since, the processing market was constrained to 75 percent of production, the remainder was assumed to be exported through East Clinton.

Table 27 presents the corn and soybean production by variety. The farm in Marshall County produced 48,455 bushels of wet mill corn, 32,878 bushels of feed corn, and 14,333 bushels of high protein soybeans. Similarly, the farm in Webster-Calhoun counties produced 48,470 bushels of wet mill corn, 17,530 bushels of feed corn, 10,792 bushels of high protein soybeans, and 9,208 bushels of high oil soybeans. Neither farm produced generic corn nor generic soybeans.

Table 28 presents livestock production for all three livestock markets and the quantity of feed fed to livestock on a per head basis. Both farms produced livestock up to their total capacity -- the farm in Marshall County produced 1159 head of livestock and the farm in Webster-Calhoun counties produce 668 head. The U.S. market only produced 3 head of livestock. Consequently, the spatial difference in markets played a large role in determining where livestock were grown. In other words, livestock production was concentrated in the

Table 27. Corn and soybean production by variety for the two farms in Marshall and Webster-Calhoun counties, in bushels.

	Corn			Soybeans		
Farm	Wet mill	Feed	Generic	High protein	High oil	Generic
Marshall	48,455	32,878	0	14,333	0	0
Webster-Calhoun	48,470	17,530	0	10,792	9,208	0

Table 28. Livestock production and ration mixture per animal by market.

		Feed ration per animal unit			
Market	Head of livestock	Wet mill corn (bushels)	Feed corn (bushels)	Generic corn (bushels)	Gluten feed (pounds)
Marshall	1,159	0	28	0	58
Webster-Calhoun	668	0	26	0	72
U.S.	3	10	64	0	0

feed producing regions in order to avoid the transport costs of shipping grain to St. Louis.

Feed rations were similar in the two farm markets. Livestock in Marshall County consumed 28 bushels of feed corn and 58 pounds of corn gluten feed per head; and livestock in Webster-Calhoun counties consumed 26 bushels of feed corn and 72 pounds of corn gluten feed. 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 4 bushels per head for fed-lambs to 89 bushels per head for dairy cows.

The U.S. livestock market fed 10 bushels of wet mill corn in combination with 64 bushels of feed corn per head of livestock. These values are rather large per head of livestock, however, the share of cattle in the U.S. grain consuming unit is roughly 42 percent relative to 7 percent in Marshall County and 5 percent in Webster-Calhoun counties. More importantly the reason for the increase corn consumption is the fact that return on raising livestock in the U.S. market was not enough to offset the sale or corn gluten feed and meal and soybean meal at the processors. The average return on raising livestock in the U.S. market was roughly $25.21 per head. This translates into an average return per bushel of corn fed of roughly 34 cents. On a per ton of feed basis the return is $12.00 per ton of feed. Given transport rates of $14.00 per ton for corn gluten feed and meal and $12.00 per ton for soybean meal, feeding the processed feed ingredients cannot be justified.

Table 29 presents corn and soybean shipments off farms by crop variety. The farm in Marshall County shipped it entire production of wet mill corn -- 48,455 bushels or 397 acres-- to the corn wet mill processor located at Cedar Rapids. This quantity satisfied the processor's entire processing capacity. The remaining corn acres were devoted to feed corn production. There was an 11 bushel residual after feeding the feed corn to livestock. This residual was shipped to the elevator at Liscomb. The entire soybean crop -- 14,333 bushels of high protein soybeans or 333 acres-- was shipped direct to the soybean processor located at Iowa Falls.

The farm in Webster-Calhoun counties produced 48,470 bushels of wet mill corn and shipped the entire quantity to the elevator at Farnhamville. Of the 17,530 bushels of feed corn grown, 166 bushels were shipped to Farnhamville. The entire high protein soybean crop --

Table 29. Corn and soybean shipments from farms, by market and by variety, in bushels.

		Truck elevators		Rail elevators		Processors	
Crop	Farm	Marshalltown	Rinard	Liscomb	Farnhamville	Cedar Rapids	Iowa Falls
Wet-mill corn	Marshall	0	0	0	0	48,455	0
	Webster-Calhoun	0	0	0	48,470	0	0
Feed corn	Marshall	0	0	11	0	0	0
	Webster-Calhoun	0	0	0	166	0	0
Generic corn	Marshall	0	0	0	0	0	0
	Webster-Calhoun	0	0	0	0	0	0
High protein soybeans	Marshall	0	0	0	0	0	14,333
	Webster-Calhoun	0	0	0	0	0	10,792
High oil soybeans	Marshall	0	0	0	0	0	0
	Webster-Calhoun	0	0	0	9,208	0	0
Generic soybeans	Marshall	0	0	0	0	0	0
	Webster-Calhoun	0	0	0	0	0	0

10,792 bushels -- were shipped directly to the processor at Iowa Falls. Together with the farm in Marshall County, these two direct shipments fulfilled the soybean processor's processing capacity. The remaining high oil soybean crop -- 9,208 bushels -- were shipped to the elevator at Farnhamville.

It is interesting to note that the truck elevators located in Marshalltown and Rinard did not receive any grain even though they were closest to the farm. This occurred for two reasons. First, the two truck elevators had higher handling costs relative to the competing elevator in the county. For example, in Webster-Calhoun counties, the elevator at Rinard had handling costs of 15.16 cents per bushel and the elevator at Farnhamville had handling costs totaling 12.32 cents per bushel, for a difference of 2.84 cents per bushel. The increased farm transport costs of shipping to Farnhamville rather than to Rinard totals approximately 1.30 cents per bushel. Consequently, from the integrated firm's perspective the elevator at Rinard should receive grain only when the elevator at Farnhamville is at capacity. Similarly in Marshall County, the handling costs at Marshalltown are 1.26 cents per bushel higher than at Liscomb. The increased farm transport costs from Marshalltown to Liscomb is 1.30 cents per bushel. The second reason was that the rail facilities at Liscomb and Farnhamville often translate into better transport rates to distant markets. These two reasons explain why the farmer bypasses the nearest elevator and shipped to the more distant elevator.

Table 30 presents the quantity of grain shipped off farms by both grain variety and vehicle type. Of the grain moving off farm in Marshall County, 48,455 bushels of wet mill corn, 11 bushels of feed corn, and 1,433 bushels of high protein soybeans moved by semi. Of the grain moving off farm in Webster-Calhoun counties, 48,470 bushels of wet mill corn, 166

Table 30. Corn and soybean shipments from farms, by vehicle type, in bushels.

Crop	Farm	Tractor- 2 wagons	Semi
Wet-mill corn	Marshall	0	48,455
	Webster-Calhoun	0	48,470
Feed corn	Marshall	0	11
	Webster-Calhoun	0	166
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

bushels of feed corn, 10,792 bushels of high protein soybeans, and 9,208 bushels of high oil soybeans moved by semi. None of the grain hauled off farms moved by a tractor pulling two 300 bushel wagons, because a tractor-wagon costs 0.2 cents per bushel per mile to transport grain compared to a costs 0.1 cents per bushel per mile a semi. The transport costs by semi are lower, because semis are cheaper to operate from a maintenance and labor perspective and, most importantly, they are faster and haul more grain per trip.

Table 31 presents the quantity of corn and soybeans shipped from elevators, by market. The only grain leaving Marshall County was 11 bushels of feed corn shipped to the

Table 31. Corn and soybean shipments from elevator, by market, in bushels.

Crop	Elevator	Cedar Rapids	Iowa Falls	St. Louis	Export
Wet-mill corn	Marshalltown	0	0	0	0
	Liscomb	0	0	0	0
	Rinard	0	0	0	0
	Farnhamville	0	0	26	48,444
Feed corn	Marshalltown	0	0	0	0
	Liscomb	0	0	0	11
	Rinard	0	0	0	0
	Farnhamville	0	0	166	0
Generic corn	Marshalltown	0	0	0	0
	Liscomb	0	0	0	0
	Rinard	0	0	0	0
	Farnhamville	0	0	0	0
High protein soybeans	Marshalltown	0	0	0	0
	Liscomb	0	0	0	0
	Rinard	0	0	0	0
	Farnhamville	0	0	0	0
High oil soybeans	Marshalltown	0	0	0	0
	Liscomb	0	0	0	0
	Rinard	0	0	0	0
	Farnhamville	0	0	0	9,208
Generic soybeans	Marshalltown	0	0	0	0
	Liscomb	0	0	0	0
	Rinard	0	0	0	0
	Farnhamville	0	0	0	0

export market from the elevator at Liscomb by rail. However, the elevator at Farnhamville shipped a combined total of 57,844 bushels of grain. Farnhamville shipped 48,444 bushels of wet mill corn to the export market. Farnhamville also shipped 26 bushels of wet mill corn and 166 bushels of feed corn to the U.S. livestock market at St. Louis. Finally, Farnhamville shipped 9,208 bushels of high oil soybeans to export. All of the grain shipped from the Farnhamville elevator moved by rail car.

At first glance it may seem odd that quality grains were shipped to the export market, since the export market does not differentiate grains according to intrinsic quality. From a integrated firm's perspective, the firm is indifferent to which variety of grain moves to the export market. In the case of corn, each variety receives the same market price regardless of variety -- $2.38 per bushel-- and each variety costs the same to produce -- $206.67 per acre in Marshall County and $197.92 per acre in Webster-Calhoun counties. The shipping and handling costs of each variety are blind to the variety type. Consequently, the choice of grain moving to export is completely arbitrary. Hence, the quality grains moving to the export market could be replaced with generic grains at no cost to the farmer.

Table 32 presents a list of the products produced at the corn wet miller located at 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 oil, 516,530 pounds of gluten feed, 98,364 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 55% HFCS. There were 1,770,600 pounds of 55% HFCS 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

Table 32. Quantity of output produced from processing corn, by corn variety, in 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
55% HFCS	1,770,600	0	0
Ethanol	0	0	0

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 55% HFCS.

Table 33 presents the quantity of products produced by the soybean processor located at 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 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 meal.

Table 34 presents the average profit per bushel by end-use for the three varieties in each crop, for each farm. Profits are calculated as if each bushel of grain was used by the

Table 33. Quantity of output produced from processing soybeans, by soybean variety, in 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. Average profit per bushel of grain by farm, variety, and end-use.

			Farm	
Crop	End-use	Variety	Marshall	Webster-Calhoun
Corn	Processing	Wet mill	$4.31	$4.31
		Feed	4.06	4.06
		Generic	4.15	4.15
	Feed	Wet mill	0.58	0.77
		Feed	0.92	1.19
		Generic	0.82	1.06
	Export	Wet mill	0.29	0.50
		Feed	0.29	0.50
		Generic	0.29	0.50
Soybeans	Processing	High protein	2.89	2.63
		High oil	2.37	2.10
		Generic	2.72	2.45
	Export	High protein	2.24	2.01
		High oil	2.24	2.01
		Generic	2.24	2.01

target end-user (ie. wet mill corn numbers assume each farm shipped wet mill corn to be processed). Wet mill corn is the most profitable corn to process, resulting in a $4.31 profit per bushel in each county. While the farm in Webster-Calhoun counties did not actually ship corn to the processor in the model, the value on the wet mill variety was calculated as if the corn were processed. Since the farm in Marshall County is closer to the processor, it is reasonable to assume that its profits per bushel would be higher than those of the farm in Webster-Calhoun. However, the farm in Marshall County plants a corn/corn/soybean rotation, whereas the farm in Webster-Calhoun produces a corn/soybean rotation. The different rotations make it approximately 20 cents per bushel more expensive to produce corn in Marshall County.

Generic corn was the next most profitable corn to process followed by feed corn. This ordering is not surprising since the corn wet mill produces starch-based products. In this case, ranking the varieties by their corresponding profit per bushel yields the same ordering as ranking them by starch content.

Once wet-milling demands are satisfied, the next most valuable use of corn was feed corn for livestock. The values in Table 34 are the average per bushel profit for corn fed to livestock in local markets, not exported or fed out of state. Feeding the feed variety of corn resulted in $0.92 profit per bushel to the farm in Marshall County and $1.19 profit per bushel to the farm in Webster-Calhoun. 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 feed corn per head to feed livestock in Webster-Calhoun. The difference in corn requirements across counties accrue to the livestock shares composing each grain consuming animal. Generic corn was the next most profitable corn variety to use as a feed source, followed by the wet mill corn.

Table 34 indicates that quality does not necessarily mean the same thing to all market agents. For example, the corn variety labeled as wet mill corn is the most valuable corn to the corn wet miller -- yielding $4.31 profit per bushel, but it is the least profitable from the perspective of the livestock feeder -- yielding $4.15 profit per bushel. The most profitable corn variety to the livestock feeder is the high protein feed corn -- yielding between $0.92 and $1.19 profit per bushel depending on farm location , while the wet-mill corn is the least valuable corn used as feed for livestock -- yielding only $0.58 and $0.77 profit per bushel.

Finally, the value of corn in the export market was approximately 29 cents per bushel in Marshall County and 50 cents per bushel in Webster-Calhoun, regardless of variety type. There are no differences accruing to variety type, because the export market was assumed to be quality indifferent. In other words, wet mill corn was assumed to command the same price as feed and generic corn in the export market.

Soybean production costs totaled $142.83 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 between farms. The remainder of the difference accrues to the difference in transportation costs. It costs approximately 1.6 cents per bushel more to ship a bushel of soybeans from the farm Webster-Calhoun counties than from the farm in Marshall.

The high protein soybeans were the most profitable to process. High protein soybeans produced on the farm in Marshall County yielded $2.89 profit per bushel, while the value of those produced on the farm in Webster-Calhoun counties was $2.63 profit per bushel. The next most profitable variety to process was generic soybeans. This variety yielded $2.72 profit per bushel in Marshall County, while the those produced on the farm in Webster-Calhoun counties yielded $2.45 profit per bushel. Finally, high oil soybeans yielded $2.37 profit per bushel in Marshall County, while those produced on the farm in Webster-Calhoun counties yielded $2.10 profit per bushel.

Given the meal and oil prices and the per bushel meal and oil yields used in model, 44% protein soybean meal was the most profitable product to produce. Since soybean meal is derived from the protein-fiber-carbohydrate portion of the soybean, the profits per bushel are directly related to the protein content of the soybeans processed. Given the 2:1 tradeoff between protein and oil content, the increased oil content of the high oil soybeans could not compensate for the decrease in soybean meal yield.

The next alternative after the processor is the export market, where soybeans are not differentiated by intrinsic quality. The value of soybeans produced on the farm in Marshall County is $2.24 per bushel, and their value if produced 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 shipped grain to Farnhamville. The handling costs at the elevator in Liscomb were approximately 2 cents higher than the handling costs at

Farnhamville. Thus, handling costs accounts for the different values across farms.

Table 35 presents the shadow values associated with each of the constraints imposed in the solution. The first two rows in Table 35 indicate the change in profits to the system of producing grain on a sustainable basis. In other words, for last acre of land planted, the negative value indicates the cost of forcing corn and soybeans to be grown simultaneously in a rotation pattern rather than simply producing the most profitable crop alone. For the farm in Marshall County the cost of complying with the cultivation practice was $36.75 per acre. In Webster-Calhoun counties, the cost imposed by the cultivation practice was $33.03 per acre.

The shadow price associated with corn processing capacity was estimated at $4.65. 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. Similarly for soybeans, the shadow price accruing to soybean processing capacity was $0.64. The shadow prices

Table 35. Shadow values associated with base solution constraints.

Constraint	Units	Shadow value
Marshall cultivation practice	$/acre	-36.75
Webster-Calhoun cultivation practice	$/acre	-33.03
Corn processing capacity	$/bushel	4.65
Soybean processing capacity	$/bushel	0.64
Marshall livestock	$/head	28.27
Webster-Calhoun livestock	$/head	28.36
Export	$/bushel	0.39

associated with Marshall County livestock and Webster-Calhoun counties livestock were $28.27 and $28.36, respectively. Relaxing the export constraint by one bushel resulted in an increase in profits of 39 cents per bushel.

Long-run solution

This long-run solution is assumes that, over time, the markets have adjusted capacities in order to handle quality differentiated grains. The constraint on cultivation practices is still in place, however. Table 36 presents the quantity of each variety of corn and soybeans produced by each farm. As expected from the shadow value on corn processing in Table 36, both farms produced the wet mill corn exclusively. The farm in Marshall County produced 81,333 bushels of wet mill corn, and the farm in Webster-Calhoun counties produced 66,000 bushels of wet mill corn. Similarly, both farms produce only high protein soybeans. The farm in Marshall 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 and Webster-Calhoun counties, in 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 -- 925 head. These animals were fed corn gluten feed from the corn wet miller exclusively. Each animal consumed 1,595 pounds of corn gluten feed.

Table 37. Livestock production and ration mixture per animal by market.

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

Table 38 presents the shipments of corn and soybeans off-farm by market. Given the results in the base solution, it is not surprising that the both farms shipped their entire production of wet mill corn direct to the corn wet miller in Cedar Rapids. The farm in Marshall County shipped 81,333 bushels of wet mill corn and the farm in Webster-Calhoun counties shipped 66,000 bushels of wet mill corn direct to the processor.

Similarly, both farms shipped their entire production 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 of high protein soybeans direct to the processor.

Table 38. Corn and soybean shipments from farms, by market and by variety, in bushels.

		Truck elevators		Rail elevators		Processors	
Crop	Farm	Marshalltown	Rinard	Liscomb	Farnhamville	Cedar Rapids	Iowa Falls
Wet-mill corn	Marshall	0	0	0	0	81,333	0
	Webster-Calhoun	0	0	0	0	66,000	0
Feed corn	Marshall	0	0	0	0	0	0
	Webster-Calhoun	0	0	0	0	0	0
Generic corn	Marshall	0	0	0	0	0	0
	Webster-Calhoun	0	0	0	0	0	0
High protein soybeans	Marshall	0	0	0	0	0	14,333
	Webster-Calhoun	0	0	0	0	0	20,000
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	0	0	0

Table 39 presents the quantities of corn and soybeans shipped off-farm by both vehicle type and grain variety. Both farms shipped their entire production 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 a tractor and two wagons than in a semi.

Table 40 presents a list of the products produced at the corn wet miller located at Cedar Rapids. The processor wet milled 147,333 bushels of wet mill corn. By-products of the wet mill process accounted for 297,020 pounds of oil, 1,570,600 pounds of gluten feed,

Table 39. Corn and soybean shipments from farms, by vehicle type, in bushels.

Crop	Farm	Tractor-wagons	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. Output produced from processing corn by corn variety, in 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
55% HFCS	5,383,600	0	0
Ethanol	0	0	0

and 299,090 pounds of gluten meal. Starch production was 5,093,300 pounds, all of which was converted to 5,383,600 pounds of glucose. The glucose was then converted to 55% HFCS. There were 5,383,600 pounds of 55% HFCS produced.

Table 41 presents the quantity of products produced by the soybean processor located at 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, no 48 percent protein soybean meal was produced, 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 42 presents the shadow values for producing an acre of each variety of grain by farm. These shadow values represent the amount of money that profits for the system would change given one acre a non-optimal variety of grain was produced. In the long run, the quality crops of feed corn and high oil corn are less valuable per acre than the generic

Table 41. Quantity of output produced from processing soybeans, by soybean variety, in 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. Shadow values per acre of production, by farm and variety, in 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

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 55% HFCS 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 corn -- 63 % starch, 2) generic corn -- 60% starch, and 3) feed corn -- 58.5% starch. 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 soybeans -- 38% protein, 2) generic soybeans 35.5% protein, and 3) high oil soybeans 31.6% protein.

When comparing these shadow prices, 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 because the shadow price an acre of high oil soybeans is $1.56 higher. Since, processed soybean output prices are not based on the variety nor 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 production and distribution costs, however, are higher in Webster-Calhoun counties. The production costs per acre of soybeans was set equal to $142.83. Given per acre yields of 42 bushels per acre for Marshall County and 40 bushels per acre for Webster-Calhoun counties, it is more costly to produce soybeans in Webster-Calhoun on a per bushel basis. Moreover, the farm in Webster-Calhoun is 8 miles farther from the processor than the farm in Marshall, costing the farm in Webster-Calhoun to more to transport soybeans to the processor. Therefore, without being given the value of the optimal soybeans, comparisons 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 43 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 where the corn originated. Combining the cultivation practices of each farm with its corresponding transport costs, the cost to produce and distribute corn to

Table 43. Shadow values of grain, by farm and variety, in cents per bushel.

Crop	Variety	Farm: Marshall	Farm: 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

the wet miller are the same across farms. Consequently, on a per bushel basis there is no difference in per bushel revenues, costs, and profits across farms. Hence, each farm experiences the same per bushel shadow values for producing corn.

Table 44 presents the profit per bushel from processing corn and soybeans in the long-run. As in the short run, wet mill corn and high protein soybeans were the most profitable varieties to process. If we base pricing on the generic corn and soybean varieties, the maximum premium the producer could expect for wet mill corn is 16 cents per bushel. The producer should expect feed corn to be discounted no more than 9 cents per bushel. Similarly for soybeans, the maximum premium paid for high protein soybeans could not exceed 17 or 18 cents per bushel, depending on origin. Finally, high oil soybeans could be discounted up to 35 cents per bushel.

Table 44. Profit per bushel of grain processed by farm and variety, in dollars per bushel.

		Farm	
Crop	Variety	Marshall	Webster-Calhoun
Corn	Wet mill	$4.33	$4.33
	Feed	4.06	4.06
	Generic	4.15	4.15
Soybeans	High protein	2.89	2.63
	High oil	2.37	2.10
	Generic	2.72	2.45

VI: DISCUSSION

Localization of production

The localization of production can best be seen from 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 possessing a comparative advantage over the farm in Webster-Calhoun counties in wet mill corn production. If the farm in Marshall County had been 4 miles west of its location in the model, the comparative advantage would have 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 at 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 grain for shipment to the processor. In fact, there was no reason for the farm in Webster-Calhoun to produce wet mill corn. It could have produced the generic variety corn with no change in profits. From this perspective, the production of wet mill corn for processing was centralized around the corn wet-miller.

From the perspective the integrated firm, moving the farm in Marshall County away from the processor would have had no effect on the results, on 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 5 miles further away from the corn wet miller, its value per bushel falls from $4.31 per bushel to $4.30 per bushel. This value is lower than value of growing wet mill corn on the farm in Webster-Calhoun, implying the farm in Webster-Calhoun counties now has a competitive advantage in producing wet mill corn. The firm, however, would still dictate that the farm in Marshall County grow wet mill corn.

From Table 34, the farm in Marshall County's next best alternative to growing wet mill corn and shipping to the wet miller, assuming livestock production is already at its maximum, is to grow generic corn and ship to 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. 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 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 which elevators and railroads play in the model. In both solutions, not one bushel of grain produced for a specific end-user moved through these channels. For example, all of the wet mill corn grown in the base solution was shipped direct from the farm in Marshall County to the corn wet miller in Cedar Rapids. Moreover, both farms shipped their entire production of high protein soybeans directly to the soybean processor, bypassing the elevators and railroads.

From the firm's perspective, moving grain to these 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 to the processor direct 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, do perform valuable task; that is, they accumulate grain. By doing so they can reduce the transactions costs of the processor, because they can replace many small contracts with individual farmers with fewer contracts with elevators. Consequently, elevators whose incremental handling and testing costs per bushel 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 there exists distant markets for quality grain. 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 transport costs from farm to elevator to costs, 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 farmer direct shipments, in terms of transport rates.

Another reason elevators cannot be assumed to excluded from the quality differentiated system is that modal choices made by farmers in the model did not reflect current shipment patterns. All grain moving off farms was shipped by semis. In reality, semis are typically owned by the large scale farmers. Those owning tractor wagon combinations will not be able to ship grain long distances to take advantage of processing markets. These farmers will be forced to sell their surplus grain to the local elevators. This implies that farmers not capable of transporting grain long distances will rely on the elevator to provide transportation to the quality markets. This is another manner in which elevators and railroads will be able to be a player in a quality differentiated market.

While these caveats to the model do not rule out elevator participation in a quality differentiated system, the long-run results of the model indicate that elevators and local cooperatives will face increasing financial stress in the advent of a quality differentiated system. The results of this study indicate that rural communities may see the abandonment of some elevators, reminiscent of the rural branch rail line abandonments which took place in the 1970s. Moreover, rural branch line abandonment may also increase as elevators located along branches are abandoned.

In order to stave off any impending crisis, one alternative to elevators and local cooperatives is to seek out niche markets for specialty grains and cater to these markets. For example, one wester Iowa cooperative processes a variety of soybeans aimed at the tofu market in Japan. There are a number of specialty markets on the horizon which elevators and local cooperatives could attempt to provide grain (McVey, Pautsch, and Baumel, 1994). Railroads should cooperate with and assist elevators and local cooperatives to locate specialty or niche markets overseas, because grain moving to these markets will travel by rail for a portion of the way and help to maintain their role as a vital player in the grain market.

Distribution of 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 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 approximately 29 cents profit per bushel for selling to the export market. Consequently, the corn miller at Cedar Rapids only has to pay the farmer \$2.39 cents per bushel, ignoring transportation costs, to draw grain away from the export market.

In contrast, if the farmer produces both grain and livestock, he can capture the entire added value of the feed variety of corn. This stems from the fact that if the farmer is both the producer and end-user of the grain, he does not have to share the value added with anyone. Consequently, the farm in Marshall County can capture \$0.92 per bushel of feed corn, and the farm in Webster-Calhoun counties can capture \$1.19 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 values 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 Webster-Calhoun area which is dominated by AGP, are less likely to be able 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's 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 $4.33 per bushel. The value of the feed corn and generic varieties of corn would increase to $4.08 per bushel and $4.17 per bushel. 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 $4.33 per bushel; the feed corn would be valued at $4.08 per bushel; and the generic variety of corn would be valued at $4.17 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 from the Marshall

County farm and $2.63 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 Marshall County and $2.45 per bushel from Webster-Calhoun counties. In the absence of any market power, soybean processors will likely be forced to pay out the entire profit per bushel to farmers.

The scenario depicted above, relies on the assumption that the processing industry behaves in a perfectly competitive manner. However, the data on corn processing indicate that two firms control 77 percent of the corn wet-milling capacity in Iowa, and that the soybean processing industry is dominated by 3 processing firms. Given these industries are fairly concentrated, gaining entry into the industries may be difficult, making the perfect competition assumption too bold.

If entry barriers exist, such as specific technologies which are not shared between firms, then capacity expansion in the long run will not likely increase to the same level as it would in the perfect competition scenario. It is in the best interest of the processing firms currently in the market to keep capacity below the perfectly competitive equilibrium level. If these firms can restrict capacity, they may be able to extract a return to asset specificity similar to an oligopoly rent. In this scenario, producers would still gain; however, the extent of the gain would be directly related to the level of capacity expansion. Under this scenario, processors will still be the main beneficiary of a quality differentiated system, implying that processors should be the ones who pick up the marketing and development costs of wet mill corn or high protein soybeans.

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 system, the short-run model was rerun where the generic varieties of corn and soybeans were the only varieties produced. In this instance, system profits for a commodity based logistics system total approximately $369,919, whereas the short-run system profits in a quality differentiate market totaled $381,530. This results in a net improvement to the system of $11,611. Most of this benefit will accrue to the processing industry.

Profits to the system increased from $381,530 in the quality differentiated short-run solution to $764,468 in the long-run solution. Since it 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 it 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.

Government policy influences

There are several time paths leading from the current non-differentiated markets to the long run solution posed in this dissertation. While this model is not capable of determining the optimal time path, one can highlight some of the issues which will become important as the quality issue evolves. Public policy makers can have a large impact upon the path actually taken. One such policy which seems to conflict with the results in the long-run solution is the current federal ethanol subsidy which provides petroleum blenders 54 cents per gallon for ethanol blended with gasoline. The long-run solution indicates that producing 55% HFCS is the most profitable activity at the corn wet miller. By subsidizing ethanol blending federal policy makers distort the market's true valuation of an activity, drawing it away from the optimal time path.

Another federal policy which has similar effects is the U.S. sugar quota. Sugar imports are restricted which, in effect, keep HFCS prices up. However, like the ethanol subsidy, the quota on sugar distorts the prices of glucose syrups and 55% HFCS, causing corn wet millers to produce above socially optimal levels of these products. Some industry sources believe that HFCS production techniques have matured enough to compete head-to-head with sugar imports, implying that sugar quota, if lifted, would have little impact on the long-run solution.

Possibly the greatest hindrance in moving from the current non-differentiated markets to that posed in the long-run solution, is continued support of grain price supports, deficiency payments to farmers, and conservation reserve program (CRP). The trade-off in production between intrinsic quality and yields has been known for quite some time (U.S. Congress, 1989). Government farm policies, like those mentioned, provide an incentive for grain producers to emphasize quantity, not quality. With such policies already in place, it will be difficult for proponents of a quality differentiated system to move forward. At the time of this writing, these and many other issues are currently being evaluated in the construction of the 1995 U.S. Farm Bill.

VI. FURTHER RESEARCH

This dissertation assumed that the only quality markets were local processing and livestock markets. Because of this assumption, quality differentiated grains did not flow through the elevator nor via the railroad. Since much of the pressure for higher quality grains is coming from grain importers (Steimel, 1990), export quality markets need to be included to account for importer requirements. Including export quality markets will likely force grain through the elevators and over the rail network, because this combination can ship grain a farther distance more efficiently than the farmer shipping direct.

Another necessary addition to the model is related to the soybean processing activities in the model. Currently, 44 percent protein soybean meal production is roughly 10 percent greater than the 48 percent protein soybean meal production. This 10 percent difference comes from the hulls being re-added to the meal to lower the protein content. In today soybean processing, hulls which are not added back into the meal can be sold as mill screenings. This activity was not an option to the soybean processor in the model, and in all likelihood was the reason that the 44 percent protein soybean meal was produced over the 48 percent protein soybeans.

In the advent of corporate livestock production, it's likely that more detailed information will be required from a feeding standpoint. In this event, the grain consuming unit used in this model may need to be disaggregated into its component livestock classes to fully capture the differences in specialty crops aimed at enhancing animal production. For example, increasing the methionine content of soybeans has large impacts in the poultry markets, but little if any impact in the cattle markets (Soybean Trait Modification Task Force, 1990). It is likely that these corporations will be very interested in the value of specialty grains aimed at increasing livestock performance, and will be concerned with their class of livestock only.

Varietal production costs were assumed to be identical across varieties within each farm. In reality, it quite plausible that enhancing intrinsic quality attributes in each crop may be accompanied by either increased costs or decreased yields. For example, some varieties of corn and soybeans produce average yields during good growing years, but well below average yields during wet or dry years. Data regarding variety production parameters need to be collected in order to accurately capture varietal returns.

The model allowed both farms to choose among tractor wagon combinations and semis to transport their grain from farm to market. Realistically, the farmer has several modal options from to choose from for shipping grain from farm to market. Other modes of transportation such as single axle trucks, tandem axle trucks, and other tractor wagon combinations should be included in the model to more accurately mimic farmer decisions.

APPENDIX A: GRAIN CONSUMING UNIT

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 fed-beef, dairy cattle, pork-sows, feed pork, and fed-lambs. These five classes were chosen because they account for over 95% of the grain fed in Iowa. For modeling purposes, the number of head for each class of livestock were constructed by estimating the average of head per livestock class over the time period from 1991 to 1994.

Three livestock feed markets were constructed in the model. Two markets were local feed markets where grain producers also produce livestock. These two markets essentially boiled down to the farmer feeding corn to livestock. In order to account for out-of-state grain sales not exported out of the United States, a third livestock market was in St. Louis was created. The grain consuming units in this market were constructed from U.S. livestock data.

Livestock production numbers on grain-fed-cattle marketed and sheep marketed were used for beef-fed and lamb-fed. The number of milk cows on farm 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 from December to May and from June to 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 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 and Calhoun levels according to the 1992 figures. Pigs per litter numbers were state averages. Table A.1 lists the number of sows farrowed by semester, the average number of pigs per litter, and the total number of pork-fed by market

Table A.1. Number of sows farrowed and pork fed, in thousands of head, and average number 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 A.2 lists the annual livestock production numbers used in the model (National Agricultural Statistics Service, 1995; Iowa Crop and Livestock Reporting Service, 1994, 1995). Over the period from 1991 to 1994, livestock figures have remained relatively constant. On a per head basis, pork fed is by far the predominant class of livestock in Marshall and Webster-Calhoun. At the national level, however, beef-fed is a larger share of the market, on a per head basis. Except for pork fed, Marshall county livestock numbers are close in magnitude to Webster-Calhoun, even though Webster-Calhoun is comprised of two counties. This tends to imply Marshall County has a comparative advantage in growing livestock.

Table A.3 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 for only a portion of the year.

Table A.4 presents the daily nutrient requirements per animal for each class of livestock (National Research Council, 1986, 1985, 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 entire livestock class within each livestock feed market. Summing across livestock classes

Table A.2. Livestock production numbers from 1991-1994, in 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
	Sheep 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
	Sheep 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
	Sheep fed	8,906	8,930	8,704	7,887	8,607
	Dairy	10,156	9,904	9,658	9,528	9,812

Table A.3. Livestock attributes by livestock class.

Livestock attributes	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 A.4. 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		

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 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 A.5. Grain consuming units in the Marshall and Webster-Calhoun markets, have relatively the same nutrient requirements. The U.S. market, represented by St. Louis, has considerably higher dry matter, metabolizable energy, and protein requirements and lower amino acid requirements than the local markets. This is attributed to the livestock mix comprising each market's grain consuming unit. The two local markets are dominated by pork-fed, whereas, the St. Louis market has strong beef-fed component. Table A.6 presents the livestock shares comprising the grain consuming units in each market.

Table A.5. Annual nutrient requirements for a grain consuming unit, by livestock market.

Nutrient	Marshall	Webster - Calhoun	St. Louis
Dry matter (lbs)	1,450.61	1,346.93	3.627.81
Metabolizable energy (Mcal)	1,890.32	1,779.41	4,214.16
Protein (lbs)	172.29	162.40	385.13
Amino acids			
Lysine (lbs)	6.64	6.77	3.81
Methionine (lbs)	3.66	3.73	2.10

Table A.6. Livestock shares comprising one grain consuming unit, by market.

Livestock class	Marshall	Webster-Calhoun	St. Louis
Beef-fed	6.47	4.98	35.64
Pork-sows	5.38	5.51	3.08
Pork-fed	86.23	87.93	49.48
Lamb-fed	1.54	1.45	5.51
Dairy cattle	0.38	0.14	6.28

APPENDIX B: SEGREGATION COSTS

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 elevators, concrete or wood elevators, rail loaders, truck shippers, land-locked, one dump pit or 10 dump pits, etc. The elevator characteristics listed play a significant role in determining how much segregating grain will cost at each facility. For example, the number of pits and the ease of redirecting grain among storage units will are parameters in determining what, if any, additional costs will be incurred from differentiating grain.

The additional testing and segregation of differentiated quality 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 segrating grain, it's 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.

Elevator fixed costs of segregating grain

The first group of costs are categorized as sunk costs from the elevators perspective. 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 absorbance 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.

$$SC_1 = \left[(P_t - P_t') \left(\frac{1}{(1+r)^n} \right) + P_t \left(\frac{P_{rt}}{100} + \frac{I}{1000} \right) \right] \frac{1}{V_t} \quad , \tag{32}$$

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 2, SC_2 represents the cost of automating the data transmission system,

$$SC_2 = \left[P_d\left(\frac{1}{1 + r)^n}\right) + P_d\left(\frac{P_{rd}}{100} + \frac{I}{1{,}000}\right)\right]\frac{1}{V_t} \quad , \qquad (33)$$

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, which are amortized over the life of the test equipment. These cost of modifying in-house computer software, SC_3, is given in equation 3,

$$SC_3 = \left[P_{cs}\left(\frac{1}{(1 + r)^n}\right) + \frac{p_u P_{cs}}{100}\right]\frac{1}{V_t} \quad , \qquad (34)$$

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 are not already doing so, if the new tests are price-determinining. Its 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 retesting. Equation 4, represents the costs associated with sample storage, SC_{4},

$$SC_4 = \left[P_{ss}\left(\frac{1}{(1 + r)^n}\right)\right]\frac{1}{V_t} \quad , \tag{35}$$

where,

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

Some elevators may be requiredto modify dump pits, elevation legs, etc., in order to become more flexible, and to switch more rapidly. Equation 5 represents the sunk costs associated with modifying the elevators handling system, SC_5,

$$SC_5 = \left[P_m\left(\frac{1}{(1 + r)^n}\right) + P_m\left(\frac{P_{rm}}{100} + \frac{I}{1{,}000}\right)\right]\frac{1}{V_t} \quad , \tag{36}$$

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 haveing a net excess of stroage by total volume. SC_6 represents the sunk costs of storage for the elevator,

$$SC_6 = \left[P_s\left(\frac{1}{(1 + r)^n}\right) + P_s\left(\frac{P_{rs}}{100} + \frac{I}{1{,}000}\right)\right]\frac{1}{V_t} \quad , \tag{37}$$

where,

P_s = price of constructing new storage, and

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

Elevator 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. Additional operator time required at testing is denoted by VC_1 in equation 7,

$$VC_1 = \frac{P_L\,(t_t - t_t')}{60B} \quad , \tag{38}$$

where,

P_L = price of labor,

t_t = time required for testing grain in differentiated system,

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

B = Bushels represented per test,

Some additional cost will be required for accounting and record-keeping, even if there is automated data handling. The dispatcher will have to make a decision and direct each load to its proper dump. A hardcopy will probably be kept as a backup reference. VC_2 represents the variable costs associated with accounting and record-keeping,

$$VC_2 = \frac{P_L\, t_a}{60B} \quad , \tag{39}$$

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 (NIR) can drift off calibration. For example, the Federal Grain Inspection Servics 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 determing. 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. VC_3 represents the variable cost of check-testing and standardization of equipment,

$$VC_3 = \frac{f_7}{100}\left(\frac{P_G}{B} + \frac{t_{aG}\,P_L}{60B}\right) \quad , \tag{40}$$

where,

f_7 = percentage of sample sent for checktest 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 its sunk cost. There is also a variable cost aspect of sample storage. VC_4 represents the variable costs of sample storage,

$$VC_4 = \frac{t_s\, P_L}{60B} \quad , \tag{41}$$

where,

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

A major reason elevator operators resist new tests is the potential for distputes with producers. 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: elevator manager's time discussing questioned results and submitted appeal samples. VC_5 represents the variable costs associated with disputes with producers,

$$VC_5 = \frac{f_9}{100}\left(\frac{P_{Lm}\, t_m}{60B} + \frac{P_G}{B}\right) \quad , \tag{42}$$

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. VC_6 is the variable cost accounting for the additional labor required at the pits,

$$VC_6 = \frac{P_L}{V_G} + \frac{f_{11}\,P_L}{60B} \quad , \tag{43}$$

where,

V_t = volume of grain tested per year,

f_{11} = subjective dump waiting time.

The probability that storage will be under-utilized 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. VC_7 represents the variable cost associated with underutilized storage,

$$VC_7 = \frac{f_{14}}{100}\left(\frac{V_s\,P_{gs}}{V_t}\right) \quad , \tag{44}$$

where,

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

V_t = volume of grain tested per year,

P_{gs} = annual oppotunity cost of storage volume,

V_s = 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 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. VC_8 is the variable cost of misgrades,

$$VC_8 = \frac{P_{ge}}{100} \Delta P_g \quad , \tag{45}$$

where,

P_{ge} = percent of misgrades,

ΔP_g = premium for quality.

To the extent that receiving and testing slowdowns drive away business, a slow down will have an opportunity cost as depicted in equation 46,

$$VC_9 = \frac{\epsilon_{vt} M V_t \left[t_{wt} + \left(\frac{60B}{V_t} + f_{11} \right) \right]}{100 V_t} \quad , \tag{46}$$

where,

ϵ_{vt} = elasticity of total volume handled relative to dump time,

M = gross elevator margin in generic grain.

Farmer costs of segregation

Producers may have to wait additional time for tests to be completed before proceding to the dump area. If the testing station is separate for the scale, this time may be zero. This cost is not a direct out-of-pocket expense. It is the opportunity cost of the producers time. The value of the producers additional waiting time is given in equation 47,

$$pc_1 = \frac{t_{wt}\, P_{LC}}{60B} \quad , \tag{47}$$

where,

t_{wt} = producer waiting time.

Another opportunity cost to the producer is the additional cost of waiting in line to dump his grain required because of pit clean-outs, spout redirections, etc. between loads. The cost to producers is estimated by equation 48,

$$pc_2 = \left[\frac{B}{V_t} + \frac{f_{11}}{60}\right] \frac{P_{LC}}{B} \quad , \tag{48}$$

with the constraint that the number of segregations is greater than the number of pits. If the number of pits is greater than the number of segregations then, pc_2 is equal to zero.

Table B.1 presents the input variables used in the elevator cost model along with the values used for each elevator. Table B.2 presents the incremental costs of segregation by component.

Table B.1. Variables used to estimate incremental elevator handling costs of quality differentiated grains.

Variable	Variable	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
Interest rate	r	10	10	10	10
Useful life (years)	n	10	10	10	10
Tester repair cost (% P_t)	P_{rt}	5	5	5	5
Insurance rate ($/$000)	I	10	10	10	10
Grain tested per year (000 bu)	V_t	1,230	1,500	1,322	10,326
Time for testing (minutes/test)	t_t	2	2	2	2
Initial testing time (minutes/test)	t_t'	1	1	1	1
Labor cost ($/hour)	P_L	10	10	10	10
Bushels per test	B	400	400	400	400
Price of data handling equipment ($)	P_d	10,000	10,000	10,000	10,000
Repair data handling equipment (% P_d)	P_{rd}	5	5	5	5
Modification for sample storage ($)	P_{ss}	2,000	2,000	2,000	2,000
Time spent storing samples (minutes)	t_s	1	1	1	1
Accounting time (minutes)	t_a	0.5	0.5	0.5	0.5
Samples check tested by FGIS,(%)	f_7	2	2	2	2

Table B.1. Continued

Cost of submitted sample grade ($/test)	P_G	10	10	10	10
Check test accounting time (minutes)	t_{aG}	5	5	5	5
Software modifications costs ($)	PCs	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 ($/hour)	P_{LM}	50	50	50	50
Manager's time spent in disputes (minutes)	t_m	12	12	12	12
Subjective additional dump waiting time (minutes)	f_{11}	2	3	3	1
Elevator modification costs ($)	P_m	0	0	0	0
Elevator modification repair costs (% P_m)	P_{rm}	5	5	5	5
Elevator storage volume (000 bu)	V_s	820	1,000	881	6,884
Annuual opportunity cost of storage volume ($/bushel)	P_{gs}	0	0	0	0
Incremental fraction of unutilized storage (%)	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

Table B.1. Continued

Storage and handling repair costs (% P_s)	P_{rs}	5	5	5	5
Elasticity of total volume handled relative to dump time (percent)	ϵ_{vt}	0.3	0.3	0.3	0.3
Gross elevator margin on generic grain ($)	M	0.08	0.08	0.08	0.08
Value of customer time ($/hour)	P_{LC}	20	20	20	20
Customer waiting time to test (minutes)	t_{wt}	1	1	1	1

Table B.2. Breakdown of incremental segregation costs by market agent, in cents per bushel.

Agent	Cost item	Marshalltown	Liscomb	Rinard	Farnhamville
Elevator	Tester	0.36	0.29	0.33	0.04
	Tester labor	0.04	0.04	0.04	0.04
	Data transmission	0.20	0.16	0.18	0.02
	Sample storage	0.07	0.06	0.07	0.04
	Accounting	0.02	0.02	0.02	0.02
	Standardization	0.05	0.05	0.05	0.05
	Software	0.04	0.04	0.04	0.01
	Disputes	0.25	0.25	0.25	0.25
	Dump area labor	0.28	0.33	0.26	0.00
	Handling modification	0.00	0.00	0.00	0.00
	Empty storage	0.33	0.33	0.33	0.33
	Misgrading risk	0.50	0.50	0.50	0.50
	New storage	0.21	0.24	0.20	0.02
	Lost volume	0.21	0.24	0.20	0.02
Producer	Test waiting	0.17	0.17	0.17	0.08
	Wait at dump area	0.57	0.65	0.52	0.00
Total cost		3.09	3.13	2.96	1.40

APPENDIX C: CORN PROCESSING COSTS

Table C.1. 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 C.1. Continued.

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 C.2. 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 C.2. Continued.

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 C.3. 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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