ESSAYS ON THE EFFECTS OF INFORMATION, PRODUCER PREFERENCES, PROSPECT THEORY, AND NONLINEAR COSTS ON A WHEAT ELEVATOR'S PROFIT, AND THE EFFECTS OF THE CONSERVATION RESERVE PROGRAM ON WHEAT ELEVATORS' MERCHANDISING MARGINS

By

SEUNGJEE HONG

Bachelor of Science
Seoul National University
Seoul, Korea
1990

Master of Science
Seoul National University
Seoul, Korea
1994

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ELEVATOR'S PROFIT, AND THE EFFECTS

OF THE CONSERVATION RESERVE

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MERCHANDISING MARGINS

Thesis Approved:

Brian Adam
Thesis Advisor

B. Wade Brorsen

James R. Fain

Harry P. Mapp

Alfred Carlozzi
Dean of the Graduate College

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ABSTRACT

Under the current grain grading and marketing system, many country elevators have paid small or no premiums to producers of high quality grain and charged small or no discounts for lower quality grain, which implies that producers receive little incentive to deliver high quality grain. Simulation analysis shows that, in addition to a spatial monopsony market structure, producers' risk aversion and lack of information about the quality of their wheat account for part of the failure of country elevators to pass on premiums and discounts. Furthermore, the level of information producers have has a bigger effect than the level of risk aversion does on elevators' incentive to pay quality-adjusted prices. The results show that prospect theory accounts for more of the failure of elevators to pay quality-adjusted prices than expected utility theory.

Key Words: producer risk attitude, information, expected utility theory, prospect theory

THE EFFECTS OF ALTERNATIVE PRODUCER RISK SPECIFICATIONS AND INFORMATION ON ELEVATOR QUALITY DISCOUNTS FOR WHEAT

Introduction

Fundamental changes in the US food system have altered traditional marketing relationships linking consumers, food retailers, food wholesalers, food processors, and farmers. The traditional marketing system efficiently processed bulk commodities into consumer products, but as consumers have increasingly demanded higher quality and diversity, the food marketing system has begun to respond.

The same trends are apparent in the US grain marketing system. Foreign buyers and domestic processors of grain have begun to demand higher quality grain and grain with particular characteristics to better meet the demands of end users. Reflecting these trends, in the last several years next-in-line (NIL) buyers have begun to charge larger discounts for grain with quality characteristics different from those they prefer, paying higher prices for higher quality grain and lower prices for lower quality grain (Kenkel, Anderson, and Attaway, 1997). However, anecdotal evidence suggests that not all elevators are passing on all or even most of those premiums and discounts to producers. This implies that the marketing system is not adequately transmitting price signals for quality characteristics. Moreover, many county elevators are not measuring grain characteristics adequately (Kenkel, Anderson, and Attaway, 1997). As a result, producers receive little incentive to deliver high quality grain. As Johnson and King (1988) note, most of the grain in traditional marketing channels passes through country elevators, so prices set by country elevators for wheat of various qualities provide important signals from world markets to producers.

For wheat, there are several possible explanations for the failure of elevators to measure quality accurately and pay quality-adjusted prices. These include lack of knowledge on the part of elevator managers about the benefits of measuring quality characteristics accurately, insufficient time for elevators to respond to market incentives by purchasing the appropriate testing equipment and making adjustments in grain receiving procedures, and the additional costs of measuring.

Other possible reasons relate to market structure and competitive pressures. To the extent that space separates an elevator's customers from the elevator's competitors, the elevator operates as a spatial monopsonist. Such firms may have a greater ability to impose discounts (Hall and Rosenfeld, 1982). In such a situation, however, paying a higher price for higher quality grain would not necessarily, at least in the short run, lead to proportionally greater purchases of higher quality grain or to greater profits, since producers of high quality grain may not have a competitive alternative market.

Conversely, if competitive pressures are strong, an elevator may believe that discounting prices for lower quality grain could cause it to lose profitable business. An elevator that imposes discounts for lower quality wheat, even while paying a higher price for high quality wheat, risks losing business if farmers believe that a competing elevator is more likely to pay them a higher price net of discounts. To the extent that maintaining volume is important to an elevator's profits, elevators may lose money by grading correctly and passing on premiums and discounts.

Elliott et al. (1997) showed that a country elevator could profit from paying producers quality-related prices if price differentials received from NIL buyers were greater than two cents. That work, however, did not consider responses by competing elevators. In subsequent work that considered competitors' responses, Elliott et al. (1998) showed that if one elevator became an early adopter, it would greatly increase profits at the expense of its competitors. They would be forced to change their grading and pricing practices in response. However, that work did not explain why more elevators have not become early adopters.

Several factors may help explain why more elevators do not become first adopters. First, most producers have incomplete information about the quality of wheat they have produced until it is graded at the elevator. They face price risk if an elevator determines that the quality is less than a predetermined standard and imposes a discount. A producer in that situation would prefer to receive an average price from an elevator that does not price according to quality. This is particularly true to the extent that quality is related to weather and not controllable by the producer. Also, losing a customer one year increases the chances the customer will not sell grain to the elevator in succeeding years.

This risk effect can also be viewed in the context of implicit contract theory. The theory was introduced by Baily (1974), Gordon (1974), and Azariadis (1975) in an attempt to explain the industrial practice of laying off unneeded workers and paying unchanged wages to the remaining work force as product demand decreased. As explained by Azariadis, when workers are risk averse and firms are risk neutral, each wage contract offered by the firm must yield a certain level of expected utility for workers. However, workers prefer a contract that offers the same wage across all possible states of nature, which gives a wage lower than the expected value of the state contingent wages. This contract is possible because the workers are willing to pay insurance premiums to eliminate uncertainty. The firms are willing to do this because they will get higher expected profits by paying a lower wage with certainty compared to the state contingent wage contract.

This implicit contract concept can be applied to the elevator profit maximization problem. If farmers are risk averse and elevators are risk neutral, then elevators may have an incentive to provide insurance for the farmers by paying one price for a range of acceptable qualities of wheat, if the price they pay is lower than the expected value of quality-adjusted prices.

Compounding the risk effect is the possibility that producers' preferences could be consistent with prospect theory (Adam and Hong, 1999). Prospect theory hypothesizes that producers dislike discounts more than they like premiums of the same magnitude. Under that hypothesis, producers would have an even greater tendency to prefer an average price than quality-adjusted prices. Under prospect theory, producers exhibit risk-seeking behavior for outcomes below a specified outcome, and risk-averse behavior for outcomes above the specified outcome.

Following Kahneman and Tversky (1979), value is treated as a function of two arguments: the asset position that serves as a reference point, and the magnitude of the change (positive or negative) from that reference point. They hypothesized that the value function for changes in wealth is normally concave above the reference point and often convex below it. That is, the marginal value of both gains and losses generally decreases with their magnitude. Also, losses loom larger than gains. The aggravation that one experiences in losing a sum of money appears to be greater than the pleasure associated with gaining the same amount. Thus, Kahneman and Tversky (1979) proposed a value function that is (i) defined on deviations from the reference point; (ii) generally concave for gains and commonly convex for losses; and (iii) steeper for losses than for gains.

Second, there is a possibility that the payment schedules offered by NIL buyers will affect the elevator's rearrangement decisions of wheat as well as its pricing strategies. When elevators receive wheat from farmers, they can either commingle or segregate the incoming wheat loads. Following Hennessy and Wahl, the elevator's decisions on commingling or segregating are dependent on the curvature characteristics of the NIL buyer's payment schedules. If the payment schedule is concave (convex), then commingling (segregating) will be favored by elevators.

In contrast to the present analysis, Hennessy and Wahl used the discount schedules for dockage in their analysis instead of payment schedules. Given this schedule, the elevators can select their discount schedules for farmers in order to maximize the profits subject to retaining the farmers by satisfying the minimum welfare level. Also, Hennessy and Wahl gave more consideration to the elevators' wheat rearrangement decision rather than to the elevator's pricing strategy.

The work here compares alternative elevator pricing decisions, assuming that elevators segregate different qualities of wheat, in order to identify factors that affect elevator' incentives to pay quality-adjusted prices. Since the payment schedule offered by NIL buyers is assumed here to be linear, assuming that elevators segregate different wheat qualities is not inconsistent with Hennessy and Wahl.

The objective of this chapter is to determine the extent to which prospect theory and an expected utility specification of producer preferences explain grain elevators' apparent reluctance to pay quality-adjusted prices for grain.

Conceptual Framework

Consider three potential market structures: (1) an elevator is a monopsonist, with no competition in its potential trade area; (2) an elevator has competitors that do not follow its lead in formulating a grading and pricing strategy; and (3) an elevator has competitors that copy its grading and pricing strategy. For each structure, an elevator (and its competitors, where applicable) considers three possible grading and pricing strategies: a) the elevator does not grade the wheat received, nor does it segregate the wheat into different qualities or pay different prices to producers for different qualities; b) the elevator grades the wheat received and segregates it to receive prices from NIL buyers that are adjusted for quality, but pays producers one price for all qualities of wheat; and c) the elevator grades and segregates the wheat delivered, and also pays producers prices that differ according to the quality of wheat they deliver.

Results by Elliott et al. (1998) showed that for structures (1) and (2), an elevator can make more profit by grading and pricing based upon the wheat qualities. But if an elevator faces structure (3) where competitors follow its practices, its potential gain from grading correctly is nearly zero; the gains to the elevator from grading correctly are offset by the additional costs. In this case, the elevator and its competitors pass on to producers the full value of any premiums and discounts received from NIL buyers.

To the extent that maintaining volume is important to elevators' profits, they may lose money by grading correctly and passing on premiums and discounts. If farmers are risk averse or their marginal utility is different for discounts than premiums, quantity purchased from farmers by elevators depends on the level of risk farmers face that their wheat may grade differently than expected and on the premium/discount schedule used by the elevator, as well as on the average price paid. These factors may limit the extent to which an elevator can profitably pay premiums and charge discounts. Therefore, the preference structure of farmers and the cost structure of elevators should be considered when the optimal strategy of elevators is derived from the profit maximization model.

Procedure

In order to focus on this chapter's purpose, assume, similar to structure (2) above, that elevator A, a representative elevator, faces six competitors located around elevator A, each 40 miles away. This is shown in Figure 1. Following Capozza and Van Order (1978), the market areas of the elevators are circular because they possess some monopsony power due to transportation cost and space.[1]

Suppose that elevator A's competitors (represented by elevator B) maximize profits, but pay the same price for all qualities. Elevator A maximizes its profits, but pays a potentially different price for each quality. Thus, elevator A solves

(1) $$\underset{P_i^A}{\text{Max}}\, Profit = \sum_{i=1}^{n}[P_{NIL_i} - P_i^A - C_{v_i}]Q_i^A - C_{fx}$$

subject to

(2) $$Q_i^A = k_i[\pi(D_i^A)^2], \text{ for all } i$$

(3) $$D_i^A = [\frac{1}{2t_i}(P_i^A - (P^B - t_i D))], \text{ for all } i,$$

while Elevator B solves

(4) $$\underset{P^B}{\text{Max}}\, Profit = \sum_{i=1}^{n}[P_{NIL_i} - P^B - C_{v_i}]Q_i^B - C_{fx}$$

subject to

(5) $$Q_i^B = k_i[\pi(D_i^B)^2], \text{ for all } i$$

(6) $$D_i^B = [\frac{1}{2t_i}(P^B - (P_i^A - t_i D))], \text{ for all } i$$

where

$D = D_i^A + D_i^B$, for all i, the distance between Elevators, B and A (miles)
P_{NIL_i} = price received from NIL buyer for quality i (\$/bu)
P_i^A = price paid to farmers by competing elevator A for i^{th} quality (\$/bu)
P^B = price paid to farmers by competing elevator B for all qualities (\$/bu)
C_{v_i} = variable costs for handling i^{th} quality (\$/bu)
C_{fx} = fixed costs for each elevator (\$)
k_i = density of production of wheat of quality i in elevator's trade area (bu/mile^2)
t_i = transportation cost for i^{th} quality (\$/bu/mile)
π = circumference of a circle divided by the diameter.

D_i^A and D_i^B are miles from the trade area boundary between the elevators to elevator A and B, respectively. The subscript i represents a wheat quality, and there are n different,

[1] The authors note that other authors have argued that an octagon shape, for example, would be more appropriate because it more completely covers the trade area, but that the results were nearly identical for either shape.

and discrete qualities.[2] This model solves simultaneously for an elevator's trade area and prices paid to producers, which in turn are functions of price paid to producers by competing elevators, transportation cost, and density of wheat production in the elevator's potential trade area.

This problem is known as an oligopsony. Competition among firms in an oligopsonistic market is inherently a setting of strategic interaction. For this reason, the appropriate tool for its analysis is game theory. A common objective in game theory model is that the equilibrium solution satisfy the Nash criterion, that each player's strategy is a best response to the strategies actually played by its rivals. Three models that have been proposed for analysis of oligopolistic markets, when firms are competing as sellers, are the Bertrand, Cournot, and Product Differentiation models (Mas-Colell, Whinston, and Green).

The Bertrand Model is a model of simultaneous price choices by profit-maximizing firms with constant returns to scale technologies, which implies the marginal cost per unit is same for the entire production level. In this case, the Nash equilibrium is that the firms set their prices equal to the marginal cost. Since the technology is the same for all firms, the equilibrium prices are also the same among all firms. In the structure of this model, the firm with the lower price will capture the entire market. In the context of grain elevators, however, the firms are competing for purchases of grain (oligopsonists) and have oligopsony power because they are separated from each other by space. Thus, by paying a higher price, an elevator extends its market area rather than capturing the entire market.

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[2] It is assumed that there are three wheat qualities in this paper, so $n = 3$.

The Cournot model is a model of simultaneous quantity choices by profit maximizing firms with constant returns to scale technologies. Given these quantity choices, price adjusts to the level that clears the market. In the Cournot model, the Nash equilibrium is the quantity level making marginal cost equal to marginal revenue for each firm assuming the rival's quantity level at decision time is given. However, this model assumes a single homogeneous good and no transportation costs. Therefore, neither the Bertrand model nor Cournot model is appropriate for the elevator profit maximization model.

When consumers perceive differences among the products of different firms, the firm will possess some market power as a result of uniqueness of its product. For instance, the presence of consumers' travel costs to a firm introduces differentiation between the two firms' products because consumers strictly prefer purchasing from one of the two firms even when the goods sell at the same price. A product differentiation model considers this fact assuming that choice variable is price and firms produce at a constant marginal cost, say c. In the above example, Nash equilibrium will be a price that makes a consumer indifferent, in which the price net of travel cost to a firm should be equal to the price net of travel cost to another firm.

Although it is difficult to characterize it, the grain elevator's profit maximization problem can be solved with a method that still maintains Nash Equilibrium criteria. Essentially, it is a product differentiation model except that there are three different qualities of wheat and the firms are buyers rather than sellers.

Analytical Solution

In the above case, the elevator's profit maximization problem can be solved using analytical methods. The analytical solutions are also helpful in justifying the numerical solutions from the simulation program used in the specifications that do not have analytical solutions. In order to solve this problem, equations (2) and (3) are substituted into equation (1), so that the objective function for Elevator A is as follow:

(7)
$$\max_{P_i^A} Profit$$
$$= (P_{NIL_1} - P_1^A - C_{v1})[\frac{1}{4}k_1\pi \frac{(P_1^A)^2 - 2P_1^A P^B + 2P_1^A Dt_1 + P^B)^2 - 2P^B Dt_1 + D^2 t_1^2}{t_1^2}]$$
$$+ (P_{NIL_2} - P_2^A - C_{v2})[\frac{1}{4}k_2\pi \frac{(P_2^A)^2 - 2P_2^A P^B + 2P_2^A Dt_2 + P^B)^2 - 2P^B Dt_2 + D^2 t_2^2}{t_2^2}]$$
$$+ (P_{NIL_3} - P_3^A - C_{v3})[\frac{1}{4}k_3\pi \frac{(P_3^A)^2 - 2P_3^A P^B + 2P_3^A Dt_3 + P^B)^2 - 2P^B Dt_3 + D^2 t_3^2}{t_3^2}]$$
$$- C_{fx}.$$

Taking first derivatives of equation (7) with regard to P_i^A gives three first order conditions:

(8)
$$\frac{\partial Profit}{\partial P_1^A} = -\frac{1}{4}k_1\pi(P_1^A - P^B + Dt_1)[\frac{3P_1^A - P^B + Dt_1 + 2C_{v_1} - 2P_{NIL_1}}{t_1^2}]$$

(9)
$$\frac{\partial Profit}{\partial P_2^A} = -\frac{1}{4}k_2\pi(P_2^A - P^B + Dt_2)[\frac{3P_2^A - P^B + Dt_2 + 2C_{v_2} - 2P_{NIL_2}}{t_2^2}]$$

(10)
$$\frac{\partial Profit}{\partial P_3^A} = -\frac{1}{4}k_3\pi(P_3^A - P^B + Dt_3)[\frac{3P_3^A - P^B + Dt_3 + 2C_{v_3} - 2P_{NIL_3}}{t_3^2}].$$

Since the optimization problem should be solved simultaneously, it is necessary to get the first order condition for elevator B. Similar to elevator A, the first order condition becomes as follow:

$$(11) \qquad \frac{dProfit}{dP^B} = -\frac{1}{4}k_1\pi(P^B - P_1^A + Dt_1)[\frac{3P^B - P_1^A + Dt_1 + 2C_{v_1} - 2P_{NIL_1}}{t_1^2}]$$

$$-\frac{1}{4}k_2\pi(P^B - P_2^A + Dt_2)[\frac{3P^B - P_2^A + Dt_2 + 2C_{v_2} - 2P_{NIL_2}}{t_2^2}]$$

$$-\frac{1}{4}k_3\pi(P^B - P_3^A + Dt_3)[\frac{3P^B - P_3^A + Dt_3 + 2C_{v_3} - 2P_{NIL_3}}{t_3^2}].$$

After solving the four first order conditions simultaneously, equilibrium prices can be expressed in terms of exogenous variables.

Producer Information about Wheat Quality

For the case where producers maximize expected revenue, it is assumed that they know with certainty the quality of their wheat, whether high, medium, or low, as in the analysis by Elliott et al. For the case where producers maximize expected utility, however, it is assumed that they have less than perfect information about the quality of their wheat. First, an extreme case is considered in which the only information producers have about the quality of their wheat is the relative proportion of each quality of wheat grown in the elevators' trade areas. They have no information about how the quality of their wheat might differ from that of other producers in their area.

More realistically, it is assumed that producers have more, but still incomplete, information about the quality of their wheat. For instance, if a producer's prior expectation is that her wheat will grade high quality, then she believes that there is a 70% probability that the wheat will grade high quality, and a 30% probability that it will grade middle quality. If her prior expectation is that the wheat will grade middle quality, then she believes there is a 15% probability that it will grade high quality, a 70% probability that it will grade middle quality, and a 15% probability that it will grade low quality. Finally, if her expectation is that the wheat will grade low quality, then she believes there is a 30% probability that it will grade middle quality, and a 70% probability that it will grade low quality.

Thus, elevators select prices knowing the proportion of each quality of wheat in their trade area, and producers select the elevators to which they will sell their wheat with prior, but incomplete, information about the quality of their wheat.

Expected Utility

If producers do not know the exact quality of their wheat until it is delivered to an elevator, they confront price risk if they deliver to elevator A. If producers are not risk neutral, the constraints in the profit-maximizing elevator are modified. In this section, a specification of expected utility is compared with a specification consistent with prospect theory. Each producer raises either high, medium, or low quality wheat, but the degree to which the producer knows the quality of her grain varies by simulation. Each producer evaluates the prices paid by elevator A and elevator B to determine which one to sell to. Similar choices made by all producers in the trade area affect each elevator's quantity received of each quality, which in turn affects its profits.

The producers' risk preferences are incorporated using a set of constraints to the elevator's profit maximization problem, as expressed in equation (1) through (6). The representative producer will sell her entire quantity of wheat to either elevator A or B depending upon which one provides the highest risk-adjusted return. Two characterizations of producers are considered here: the first is where producers maximize expected utility, and the second is where producers maximize "prospects" in the context of prospect theory.

Expected utility functions can be classified by three types of risk attitudes, such as decreasing absolute risk aversion (DARA), constant absolute risk aversion (CARA), and increasing absolute risk aversion (IARA). The negative exponential utility (NEU) function is characterized by CARA, which implies that the risk aversion level for decision makers is constant regardless of changes in the decision maker's wealth. The logarithmic utility (LU) function is characterized by DARA, which implies that the risk aversion level for decision makers is decreasing with increases in wealth. An IARA-type utility function shows increasing risk aversion while the decision maker's wealth is increasing, which is rarely observed in the real world (Robison and Barry). Also, since results by Adam et al. suggest that for the small range of outcomes to be evaluated by producers in the framework considered here, only the CARA specification is used, in the form of a negative exponential utility function.

The expected utility constraints for both elevators are as follows.

For elevator A to receive a producer's wheat,

$$\text{(12)} \qquad \mathrm{EU^A} = \sum_{i=1}^{n} p_i U[(P_i^A - t_i D_i^A) Q_i^A] \geq U\{\sum_{i=1}^{n} [(P^B - t_i D_i^B) Q_i^B]\} = \mathrm{EU^B}$$

For elevator B to receive the wheat,

$$\text{(13)} \qquad \mathrm{EU^B} = U\{\sum_{i=1}^{n} [(P^B - t_i D_i^B) Q_i^B]\} \geq \sum_{i=1}^{n} p_i U[(P_i^A - t_i D_i^A) Q_i^A] = \mathrm{EU^A}$$

where p_i = probability that a producer's wheat will be graded in such a way as to receive P_i^A. The negative exponential utility function is defined as:

$$\text{(14)} \qquad U(y) = 1 - \exp(-\lambda y).$$

where y = the producer's revenue, and λ is the constant Arrow-Pratt coefficient of absolute risk aversion across all levels of wealth. If this value is close to zero, the producer is risk neutral, and the more it differs from zero, the more risk averse is the producer.

The effects of different risk preferences on the elevator's optimal prices can be examined by comparing the results from different values of λ. In this paper three levels of producer risk aversion are considered. The Arrow-Pratt risk aversion parameter associated with the medium risk aversion level is adapted form literature that either elicited producers' risk aversion levels or estimated the level based on production responses (Lins, Gabriel, and Sonka, 1981; Raskin and Cochran, 1986). Slight risk averse and strong risk aversion levels are simple adjustments of this estimated level to capture a broader range of producer risk preferences.

For solving these optimization problems in practice, an iterative procedure is used. First, elevator A solves its profit maximization problem (equations (1) - (3)), given a starting value of Q_i^A and a value for elevator B's price P_i^B. From this optimization D_i^A are determined since $D_i^A + D_i^B = D$, the distance between elevator A and its competitor B.

Second, given elevator A's prices, elevator B solves for its profit maximizing prices P_i^B with Q_i^B determined by:

(15) $$\sum_{i=1}^{n} p_i U[(P_i^A - t_i D_i^A) Q_i^A] = U\{\sum_{i=1}^{n} [(P^B - t_i (D - D_i^A) Q_i^B].$$

B's prices are substituted into elevator A's optimization, and the iterations continue until solution values for P_i^A and P^B stabilize at their optimal values.

It is assumed that there are three wheat qualities and the relative proportions of each quality are known. Therefore, the subscript i is to be 1, 2, or 3, representing 'high', 'middle', and 'low' qualities of wheat. Wheat of each quality is assumed to be distributed evenly in the elevator's trade area. The proportion of each of those qualities can be varied to gauge the effect of alternate quality distributions. These distributions are based on wheat quantity from 1996, 1997, and 1998 wheat harvest data (Kenkel, Anderson, Attaway, 1997).

Cumulative Prospect Theory

Expected utility theory has been widely used in normative and descriptive models of decision making under uncertainty for several decades. But this theory has been challenged by five major phenomena, which violate major tenets proposed by expected utility theory. These five phenomena are as follows (Kahneman and Tversky, 1979; Tversky and Kahneman, 1992). 1) Framing effects - variations in the framing of options (e.g., in terms of gains or losses) yield systematically different preferences. 2) Nonlinear preferences - the utility of a risky prospect is not linear in outcome probabilities. 3) Source dependence - people's willingness to bet on an uncertain event depends on both the degree of uncertainty and its source. 4) Risk seeking - risk seeking behavior is consistently observed in the choice of small probability of winning a large prize and the choice between a sure loss and a substantial probability of a larger loss. 5) Loss aversion - asymmetry between gains and losses reflects the tendency for individuals to be more sensitive to reductions than to increases in their levels of well-being.

Kahneman and Tversky (1979) developed a model of choice, called prospect theory, which is not affected by the above violations of expected utility theory. Whereas expected utility focuses on wealth levels, prospect theory focuses on gains and losses. The major aspects of prospect theory are 1) a value function that is concave for gains, convex for losses, and steeper for losses than for gains, and 2) a weighting function that is a nonlinear transformation of the probability scale, which increases decision weight of small probabilities and decreases decision weight of moderate and high probabilities. Kahneman and Tversky (1979) used a weighting function which was a monotonic transformation of outcome probabilities. But this weighting function had two problems. First, it did not always satisfy stochastic dominance. Second, it was not readily extended to prospects with a large number of outcomes.

In order to overcome these problems, Tversky and Kahneman (1992) presented a cumulative version of prospect theory, which adopted the rank-dependent or cumulative functional proposed by Quiggin (1982) and Schmeidler (1989). This version of prospect theory transforms the entire cumulative distribution function and applies separately to gains and losses rather than transforming each probability separately. This development enables prospect theory to extend to uncertain as well as to risky prospects with any number of outcomes (Tversky and Kahneman, 1992).[3]

[3] Following Robison and Barry, an uncertain event becomes risky if the outcomes of the uncertain event alter the decision maker's well-being. Usually an uncertain event is defined as one that has more than one possible outcome, and the likelihood of the outcomes can be described by probability distributions. This definition is different from that of Knight. He defined a risky situation as one in which a decision maker faces a situation similar to others which have occurred in the past and information about the outcomes of previous choices can be used to estimate probability functions. If there is no empirical basis for the formation of probability distribution, this situation is considered an uncertain event. For a more complete discussion about risk and uncertainty, see Robison and Barry (pp:13-14).

Prospect theory distinguishes two phases in the choice process: an early phase of editing and a subsequent phase of evaluation. The editing phase consists of a preliminary analysis of the offered prospects, which often yields a simpler representation of these prospects. This phase is needed for simplifying subsequent evaluation and choice. Editing consists of the application of several operations that transform the outcomes and probabilities associated with the offered prospects (coding, combination, segregation, and cancellation). In the second phase, the edited prospects are evaluated using value function and weighting functions, and the prospect of highest value is chosen.

The overall value of an edited prospect, denoted V, is expressed in terms of two scalars, a weighting function π and a value function ν. Following Tversky and Kahneman (1992), the value function is (i) defined on deviations from the reference point, (ii) generally concave for gains and commonly convex for losses, (iii) steeper for losses than for gains. The third property of the value function implies that the aggravation that one experiences in losing a sum of money appears to be greater than the pleasure associated with gaining the same amount (loss aversion concept).

They proposed the following value function for a set of possible outcome x_i:

$$v(x_i) = \begin{cases} x_i^{\alpha} & \text{if } x_i \geq 0 \\ -\gamma(-x_i)^{\beta} & \text{if } x_i < 0, \end{cases} \tag{16}$$

where γ is the loss aversion coefficient. Tversky and Kahneman (1992) have estimated α and β to be 0.88 and γ to be 2.25.[4] The value function is shown in Figure 2.

[4] The parameter estimates of value and weighting functions were estimated using experimental data collected by Tvesky and Kahneman (1992). The subjects were 25 graduate students from Berkeley and Stanford with no special training in decision theory. Therefore, there is a possibility that these parameter values are not consistent with Oklahoma wheat producers' preferences. However, they focused on the qualitative properties of the data rather than on exact parameter estimates. If wheat producers maintain the

In order to complete evaluation of an outcome, the value calculated by equation (16) should be combined with a decision weight, which is transformed by a weighting function. The weighting function has the following properties. 1) Decision weights measure the impact of events on the desirability of prospects, and not merely the perceived likelihood of these events. 2) π is an increasing function of p (the probability of the event occurring), with $\pi(0) = 0$ and $\pi(1) = 1$. That is, outcomes contingent on an impossible event are ignored, and the scale is normalized so that $\pi(p)$ is the ratio of the weight associated with the probability p to the weight associated with the certain event. 3) Subadditivity: $\pi(rp) > r\pi(p)$ where r is a constant for $0 < r < 1$. 4) Subcertainty: $\pi(p) + \pi(1-p) < 1$ for all $0 < p < 1$. 5) Subproportionality: for a fixed ratio of probabilities, the ratio of the corresponding decision weights is closer to unity when the probabilities are low than when they are high (Kahneman and Tversky, 1979).

The weighting function has been developed further by Prelec (1998). Following his results, the weighting function $\pi(p)$ is regressive (first $\pi(p) > p$, then $\pi(p) < p$), s-shaped (first concave, then convex), and asymmetrical (intersection the diagonal at about 1/3).

For calculating π_i, a decision weight is assigned to outcome x_i using the $w(p)$ approximation for w proposed by Tversky and Kahneman (1992),

(17)
$$w(p) = \frac{p^r}{(p^r + (1-p)^r)^{1/r}},$$

where r is estimated at 0.61 in the domain of gains and 0.69 in the domain of losses.

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qualitative properties proposed by prospect theory, these parameter estimates can still give meaningful implications.

If 0.61 is used for r in the domain of gains, then the weighting function has an invariant fixed point and inflection point at 0.34, and if 0.69 for r in the domain of losses, then it has an invariant fixed point and inflection point at around 0.37. The above approximation $w(p)$ for $\pi(p)$ is also consistent with regressive (first $\pi(p) > p$, then $\pi(p) <$ p), and s-shaped (first concave, then convex) properties. Weighting functions are presented in Figure 3.

Finally, the overall value of a prospect can be calculated as

$$V(G) = \sum \pi_i v(x_i) \,. \tag{18}$$

In the elevator profit maximization problem, there are two possible prospects given to a producer, prospect A and prospect B. Prospect A has three possible outcomes and each outcome is assigned to a probability that depends on the proportion of wheat quality. Prospect B has only one sure outcome, so its probability is one. In both prospects, the outcomes are the net prices that are adjusted by transportation costs and distances from each elevator. For a producer located a distance DP from elevator A, the outcomes of prospect A are $P_1^A - tDP^A = x_1$ for high quality wheat, $P_2^A - tDP^A = x_2$ for middle quality wheat, and $P_3^A - tDP^A = x_3$ for low quality wheat, and the outcomes of prospect B are $P^B - t(D - DP^A) = x$. Define p_h, p_m, and p_l as probabilities for high, middle, and low quality. Then the two prospects are represented as follows: $(x_3, p_l; x_2, p_m; x_1, p_l)$ for prospect A and $(x, 1)$ for prospect B. These prospects will be reformulated through editing to simplify evaluation.

The editing phase for these prospects is coding. Coding is the process that transforms an outcome of a prospect into gains and losses relative to some neutral reference point, which is usually defined as the current asset position. However, the location of the reference point, and the consequent coding of outcomes as gains and losses, can be affected by the expectations of the decision maker (Kahneman and Tversky, 1979). In the elevator problem, a producer can expect that the net price paid by elevator B, which is adjusted by transportation costs, is a sure outcome when he decides to sell his whole wheat to elevator B, and that he receives a state contingent net price depending upon the wheat quality when he decides to sell his wheat to elevator A. Therefore, the producer could consider the net price paid by elevator B as a reference point. In this case, comparing the net prices of elevator A with that of elevator B gives gains and losses of prospect A. After coding, prospect A is reformulated as $(x_l, p_l; x_m, p_m; x_h, p_h)$ and prospect B is described as $(0,1)$, where $x_l = x - x_3$, $x_m = x - x_2$, and $x_h = x - x_1$.

In the evaluation phase, the reformulated prospect A is evaluated by a value function (equation (16)), a weighting function (equation (17)), and equation (18) depending on the sign of the outcome. Prospect B does not need this evaluation process because its prospect value should be always zero. Therefore, the decision problem of the producer is simplified as choosing prospect A if the prospect utility of prospect A is positive, and choosing prospect B if it is negative. The results from this specification will be compared to results from the expected utility specifications used in equation (15).

Results

Producers Maximize Expected Net Revenue

For the case where producers maximize net revenue (Table 1), elevators pass on to producers 70% of the price differentials received from next-in-line buyers, so that they receive a margin of 32¢/bu. for high quality, 29¢/bu. for middle quality, and 26¢/bu. for low quality wheat. Quantities received and trade area radius vary directly with their prices. Elevator B pays an average price for all qualities, which is just lower than elevator A's price for middle quality wheat.

The trade area boundary for high quality wheat is 23.35 miles from elevator A, or 3.35 miles beyond the midpoint between the elevators. For middle quality wheat the boundary is just 0.32 miles beyond the midpoint, and for low quality wheat, is 2.71 miles less than the midpoint. These radii are consistent with the prices paid and quantities received: higher prices relative to elevator B's prices result in a larger trade area and high quantities received. By pricing according to quality, elevator A achieves a profit of $557,851, about 20% higher than elevator B's profit.

Producers Maximize Expected Utility

For the case where producers maximize expected utility and have no information about the quality of their crop (Tables 2, 3, and 4), the probability a producer will deliver a particular quality of wheat is equal to its proportion of total production in the trade area. In this simulation, producers have a 1/3 chance that their wheat will grade high quality, 1/3 that it will grade middle quality, and 1/3 that it will grade low quality. Because they don't know the quality of their wheat, producers select an elevator that will pay the highest risk-adjusted price for an evenly-weighted portfolio of all the possible qualities. As Tables 2, 3, and 4 indicate, this implies that elevators have little incentive to pay quality-adjusted prices, since risk averse producers prefer a certain average price than a random price with an expected value equal to the average price. In Table 2, Elevator A pays prices that reflect 30% of the price differences paid by NIL buyers by setting those prices high enough so that the average of the three prices is $4.613/bu, which is $0.013/bu higher than Elevator B's price. This results in margins of $0.35/bu. for high quality wheat, $0.28/bu. for middle quality wheat, and $0.23/bu. for low quality wheat. The radius of elevator A's trade area is slightly bigger than elevator B's (20.02 miles compared to 19.98 miles), and its profits are 3/10 of a percent higher than elevator B's profits.

As Table 3 and 4 indicate, for producers that are more risk averse, elevator A optimizes profits by paying nearly the same price for all three qualities. Its profits are only 1/100 of a percent higher than elevator B's profits. Because of producers' risk aversion, elevator A does not find it profitable to pay quality-adjusted prices. These results indicate the risk aversion is very important when producers have no information about the quality of their wheat compared to the overall quality of wheat in their region.

In contrast, results for the case where producers have additional, but still incomplete, information about the quality of their wheat indicate that elevators pay nearly the same high price for high- and middle quality wheat and a much lower price for low quality wheat (Tables 5 through 7).[5] Thus, the prices for high- middle quality wheat are higher than those paid by Elevator B, and the price for low quality wheat is lower than Elevator B's price. Profits at each elevator decline by slightly more than 1/10 of one percent, compared to the expected revenue case. Increasing producers' level of risk aversion changes those results very little, except that elevator A's profits are very slightly reduced and elevator B's profits are slightly enhanced as level of risk aversion increases (Tables 6 and 7).

Tables 8 through 10 show the results for the case where producers have almost complete information about the quality of their wheat.[6] These results are very similar to those for the case where producers have incomplete information about the quality of their wheat except that there is \$0.04/.bu. difference between the price for high quality and middle quality of wheat and \$0.09/bu. difference between the price for middle and low quality of wheat. Also, elevator B's profits compared to elevator A's profits are no longer increasing as the producer's risk aversion increases. These results imply that as producers' information about the quality of their wheat is more complete, the level of risk aversion becomes less important in producers selling decisions, and hence, elevators' pricing strategies.

To summarize the results of tables 2 through 10, when producers have no information about the quality of their wheat, producers' risk preferences are important in explaining elevators' pricing strategies. But as producers have more information about

[5] As explained above, this incomplete information takes the form that if, for example, a producer has a prior expectation that her wheat will grade high quality, then she has a 70% (posterior) probability that her wheat will grade high quality and 30% probability that it will grade middle quality.

[6] This almost complete information takes the form that if, for example, a producer has a prior expectation that her wheat will grade high quality, then she has a 90% (posterior) probability that her wheat will grade high quality and 10% probability that it will grade middle quality.

the quality of their wheat, risk preferences matter little while the level of information becomes very important.

Producers Maximize Prospect Value

Table 11 indicates than when producers' preferences can be characterized by prospect theory, Elevator A's prices differ between qualities by $0.05/bu. compared to the risk neutral case in which there was a difference of $0.07/bu. Thus, prospect theory helps explain part of country elevators' reluctance to pass premiums and discounts on to producers.

Comparing Table 11 with the expected utility results when producers have "some information" (Tables 5, 6, and 7) shows that the prices seem to be more related to quality differences than prices under expected utility. However, Elevator A achieves only a 1.5% profit advantage over Elevator B by paying quality-adjusted prices, whereas under the expected utility specification, the advantage from paying quality-adjusted prices is approximately 20%. Thus, if producers' preferences can be characterized more appropriately by prospect theory than by expected utility, elevators face a much smaller potential gain from paying quality-adjusted prices. This provides a better, though still partial, explanation of why more elevators do not become "early adopters" in paying quality-adjusted prices to producers.

Conclusions

A cursory review of the results suggests that prospect theory does not provide any advantage over expected utility theory to explain why elevators do not pay quality-adjusted prices. The optimal price structure for a profit-maximizing elevator is to pass on to producers roughly half of the premiums/discounts it receives from NIL buyers. Presumably, an elevator would choose to do this, and its competitors would be forced to follow. As Elliott et al. showed, if this happened, elevators would pass on all quality-based premiums/discounts to producers.

Further review of the prospect theory results, though, suggests that an elevator's potential profit gain from paying quality-adjusted prices is relatively small, representing only a 1.5% advantage over its competitors that do not pay quality-adjusted prices. If other factors, such as producer loyalty, are important to the elevator's management, this potential gain may be too small to risk losing that loyalty.

Further research should examine the effects of alternative levels of information producers have about the quality of their wheat in a prospect theory context. Adam and Hong found in an expected utility framework, and the current results are consistent with their findings, that the level of information producers have has a bigger effect than level of risk aversion does on elevators' incentive to pay quality-adjusted prices. Also, the incentive by elevator managers to promote producer loyalty should be examined more carefully.

Table 1. Producers Maximize Expected Revenue and Know Crop Quality: P_{NIL1}=\$5.00, P_{NIL2}=\$4.90, P_{NIL3}=\$4.80

Price (\$/bu)	Quantity (bu)	Trade Area Radius (miles)	Elevator Profit (\$)
Elevator A			
P_{f1} = \$4.68	Q_1 = 1,241K	$Radius_1$ = 23.35	
P_{f2} = \$4.61	Q_2 = 940K	$Radius_2$ = 20.32	\$557,851
P_{f3} = \$4.54	Q_3 = 681K	$Radius_3$ = 17.29	
Elevator B			
P_{f1} = \$4.60	Q_1 = 631K	$Radius_1$ = 16.65	
P_{f2} = \$4.60	Q_2 = 882K	$Radius_2$ = 19.68	\$464,605
P_{f3} = \$4.60	Q_3 = 1,174K	$Radius_3$ = 22.71	(Diff = \$93,246)

Table 2. Producers Maximize Expected Utility but Don't Know Crop Quality (AP = 0.00176): P_{NIL1}=\$5.00, P_{NIL2}=\$4.90, P_{NIL3}=\$4.80

Price (\$/bu)	Quantity (bu)	Trade Area Radius (miles)	Elevator Profit (\$)
Elevator A			
P_{f1} = \$4.68	Q_1 = 911,452	$Radius_1$ = 20.01	
P_{f2} = \$4.62	Q_2 = 911,452	$Radius_2$ = 20.01	\$500,370
P_{f3} = \$4.54	Q_3 = 911,452	$Radius_3$ = 20.01	
Elevator B			
P_{f1} = \$4.61	Q_1 = 909,834	$Radius_1$ = 19.99	
P_{f2} = \$4.61	Q_2 = 909,834	$Radius_2$ = 19.99	\$500,000
P_{f3} = \$4.61	Q_3 = 909,834	$Radius_3$ = 19.99	(Diff = \$370)

Table 3. Producers Maximize Expected Utility but Don't Know Crop Quality (AP = 0.088): P_{NIL1}=\$5.00, P_{NIL2}=\$4.90, P_{NIL3}=\$4.80

Price (\$/bu)	Quantity (bu)	Trade Area Radius (miles)	Elevator Profit (\$)
Elevator A			
P_{f1} = \$4.62	Q_1 = 910,763	$Radius_1$ = 20.00	
P_{f2} = \$4.61	Q_2 = 910,763	$Radius_2$ = 20.00	\$500,389
P_{f3} = \$4.61	Q_3 = 910,763	$Radius_3$ = 20.00	
Elevator B			
P_{f1} = \$4.61	Q_1 = 910,523	$Radius_1$ = 20.00	
P_{f2} = \$4.61	Q_2 = 910,523	$Radius_2$ = 20.00	\$500,328
P_{f3} = \$4.61	Q_3 = 910,523	$Radius_3$ = 20.00	(Diff = \$61)

Table 4. Producers Maximize Expected Utility but Don't Know Crop Quality (AP = 0.264): P_{NIL1}=\$5.00, P_{NIL2}=\$4.90, P_{NIL3}=\$4.80

Price (\$/bu)	Quantity (bu)	Trade Area Radius (miles)	Elevator Profit (\$)
Elevator A			
P_{f1} = \$4.61	Q_1 = 910,724	$Radius_1$ = 20.00	
P_{f2} = \$4.61	Q_2 = 910,724	$Radius_2$ = 20.00	\$500,415
P_{f3} = \$4.61	Q_3 = 910,724	$Radius_3$ = 20.00	
Elevator B			
P_{f1} = \$4.61	Q_1 = 910,562	$Radius_1$ = 20.00	
P_{f2} = \$4.61	Q_2 = 910,562	$Radius_2$ = 20.00	\$500,373
P_{f3} = \$4.61	Q_3 = 910,562	$Radius_3$ = 20.00	(Diff = \$42)

Table 5. Producers Maximize Expected Utility and Have Some Information about Crop Quality (AP = 0.00176): P_{NIL1}=\$5.00, P_{NIL2}=\$4.90, P_{NIL3}=\$4.80

Price (\$/bu)	Quantity (bu)	Trade Area Radius (miles)	Elevator Profit (\$)
Elevator A			
P_{f1} = \$4.66	Q_1 = 1,137K	$Radius_1$ = 22.35	
P_{f2} = \$4.66	Q_2 = 1,022K	$Radius_2$ = 21.30	\$551,006
P_{f3} = \$4.51	Q_3 = 696K	$Radius_3$ = 17.48	
Elevator B			
P_{f1} = \$4.61	Q_1 = 709K	$Radius_1$ = 17.65	
P_{f2} = \$4.61	Q_2 = 796K	$Radius_2$ = 18.70	\$457,304
P_{f3} = \$4.61	Q_3 = 1,154K	$Radius_3$ = 22.52	(Diff = \$93,702)

Note: The quality information matrix of the producers is assumed as below and each row corresponds to each quality of wheat from high to low:

$$\begin{bmatrix} 0.7 & 0.3 & 0 \\ 0.15 & 0.7 & 0.15 \\ 0 & 0.3 & 0.7 \end{bmatrix}$$

Table 6. Producers Maximize Expected Utility and Have Some Information about Crop Quality (AP = 0.088): P_{NIL1}=\$5.00, P_{NIL2}=\$4.90, P_{NIL3}=\$4.80

Price (\$/bu)	Quantity (bu)	Trade Area Radius (miles)	Elevator Profit (\$)
Elevator A			
P_{f1} = \$4.66	Q_1 = 1,137K	$Radius_1$ = 22.35	
P_{f2} = \$4.66	Q_2 = 1,022K	$Radius_2$ = 21.30	\$551,009
P_{f3} = \$4.51	Q_3 = 696K	$Radius_3$ = 17.48	
Elevator B			
P_{f1} = \$4.61	Q_1 = 709K	$Radius_1$ = 17.65	
P_{f2} = \$4.61	Q_2 = 796K	$Radius_2$ = 18.70	\$457,513
P_{f3} = \$4.61	Q_3 = 1,154K	$Radius_3$ = 22.52	(Diff = \$93,496)

Note: The quality information matrix of the producers is assumed as below and each row corresponds to each quality of wheat from high to low:

$$\begin{bmatrix} 0.7 & 0.3 & 0 \\ 0.15 & 0.7 & 0.15 \\ 0 & 0.3 & 0.7 \end{bmatrix}$$

Table 7. Producers Maximize Expected Utility and Have Some Information about Crop Quality (AP = 0.264): P_{NIL1}=\$5.00, P_{NIL2}=\$4.90, P_{NIL3}=\$4.80

Price (\$/bu)	Quantity (bu)	Trade Area Radius (miles)	Elevator Profit (\$)
Elevator A			
P_{f1} = \$4.66	Q_1 = 1,138K	$Radius_1$ = 22.31	
P_{f2} = \$4.66	Q_2 = 1,031K	$Radius_2$ = 21.28	\$550,069
P_{f3} = \$4.51	Q_3 = 699K	$Radius_3$ = 17.52	
Elevator B			
P_{f1} = \$4.61	Q_1 = 712K	$Radius_1$ = 17.69	
P_{f2} = \$4.61	Q_2 = 798K	$Radius_2$ = 18.72	\$458,069
P_{f3} = \$4.61	Q_3 = 1,150K	$Radius_3$ = 22.48	(Diff = \$92,000)

Note: The quality information matrix of the producers is assumed as below and each row corresponds to each quality of wheat from high to low:

$$\begin{bmatrix} 0.7 & 0.3 & 0 \\ 0.15 & 0.7 & 0.15 \\ 0 & 0.3 & 0.7 \end{bmatrix}$$

Table 8. Producers Maximize Expected Utility and Have More Information about Crop Quality (AP = 0.00176): P_{NIL1}=\$5.00, P_{NIL2}=\$4.90, P_{NIL3}=\$4.80

Price (\$/bu)	Quantity (bu)	Trade Area Radius (miles)	Elevator Profit (\$)
Elevator A			
P_{f1} = \$4.67	Q_1 = 1,169K	$Radius_1$ = 22.66	
P_{f2} = \$4.63	Q_2 = 998K	$Radius_2$ = 20.94	\$550,372
P_{f3} = \$4.54	Q_3 = 680K	$Radius_3$ = 17.28	
Elevator B			
P_{f1} = \$4.60	Q_1 = 685K	$Radius_1$ = 17.34	
P_{f2} = \$4.60	Q_2 = 827K	$Radius_2$ = 19.06	\$458,069
P_{f3} = \$4.60	Q_3 = 1,175K	$Radius_3$ = 22.72	(Diff = \$85,192)

Note: The quality information matrix of the producers is assumed as below and each row corresponds to each quality of wheat from high to low:

$$\begin{bmatrix} 0.9 & 0.1 & 0 \\ 0.05 & 0.9 & 0.05 \\ 0 & 0.1 & 0.9 \end{bmatrix}$$

Table 9. Producers Maximize Expected Utility and Have More Information about Crop Quality (AP = 0.088): P_{NIL1}=\$5.00, P_{NIL2}=\$4.90, P_{NIL3}=\$4.80

Price (\$/bu)	Quantity (bu)	Trade Area Radius (miles)	Elevator Profit (\$)
Elevator A			
P_{f1} = \$4.67	Q_1 = 1,169K	$Radius_1$ = 22.65	
P_{f2} = \$4.63	Q_2 = 997K	$Radius_2$ = 20.93	\$549,825
P_{f3} = \$4.54	Q_3 = 681K	$Radius_3$ = 17.29	
Elevator B			
P_{f1} = \$4.60	Q_1 = 685K	$Radius_1$ = 17.35	
P_{f2} = \$4.60	Q_2 = 828K	$Radius_2$ = 19.07	\$464,955
P_{f3} = \$4.60	Q_3 = 1,174K	$Radius_3$ = 22.71	(Diff = \$84,870)

Note: The quality information matrix of the producers is assumed as below and each row corresponds to each quality of wheat from high to low:

$$\begin{bmatrix} 0.9 & 0.1 & 0 \\ 0.05 & 0.9 & 0.05 \\ 0 & 0.1 & 0.9 \end{bmatrix}$$

Table 10. Producers Maximize Expected Utility and Have More Information about Crop Quality (AP = 0.264): P_{NIL1}=\$5.00, P_{NIL2}=\$4.90, P_{NIL3}=\$4.80

Price (\$/bu)	Quantity (bu)	Trade Area Radius (miles)	Elevator Profit (\$)
Elevator A			
P_{f1} = \$4.67	Q_1 = 1,167K	$Radius_1$ = 22.64	
P_{f2} = \$4.63	Q_2 = 996K	$Radius_2$ = 20.92	\$549,760
P_{f3} = \$4.54	Q_3 = 682K	$Radius_3$ = 17.31	
Elevator B			
P_{f1} = \$4.60	Q_1 = 686K	$Radius_1$ = 17.36	
P_{f2} = \$4.60	Q_2 = 829K	$Radius_2$ = 19.08	\$465,130
P_{f3} = \$4.60	Q_3 = 1,173K	$Radius_3$ = 22.69	(Diff = \$84,630)

Note: The quality information matrix of the producers is assumed as below and each row corresponds to each quality of wheat from high to low:

$$\begin{bmatrix} 0.9 & 0.1 & 0 \\ 0.05 & 0.9 & 0.05 \\ 0 & 0.1 & 0.9 \end{bmatrix}$$

Table 11. Producers Maximize Prospect Value and Have Some Information about Crop Quality: P_{NIL1}=\$5.00, P_{NIL2}=\$4.90, P_{NIL3}=\$4.80 (B's Prices Used As Reference Points)

Price (\$/bu)	Quantity (bu)	Trade Area Radius (miles)	Elevator Profit (\$)
Elevator A			
P_{f1} = \$4.65	Q_1 = 1,086K	$Radius_1$ = 21.84	
P_{f2} = \$4.60	Q_2 = 875K	$Radius_2$ = 19.60	\$534,081
P_{f3} = \$4.55	Q_3 = 684K	$Radius_3$ = 17.33	
Elevator B			
P_{f1} = \$4.60	Q_1 = 751K	$Radius_1$ = 18.16	
P_{f2} = \$4.60	Q_2 = 947K	$Radius_2$ = 20.40	\$525,763
P_{f3} = \$4.60	Q_3 = 1,170K	$Radius_3$ = 22.67	(Diff = \$8,318)

Note: The quality information matrix of the producers is assumed as below and each row corresponds to each quality of wheat from high to low:

$$\begin{bmatrix} 0.7 & 0.3 & 0 \\ 0.15 & 0.7 & 0.15 \\ 0 & 0.3 & 0.7 \end{bmatrix}$$

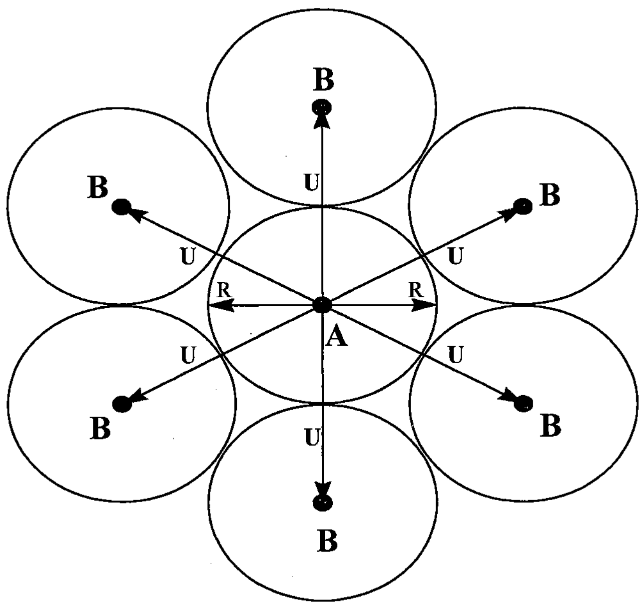


Figure 1. Spatial Competition Model (Capozza and van Order, 1978)

Figure 2. Graphical Representation of Value Function of Prospect Theory

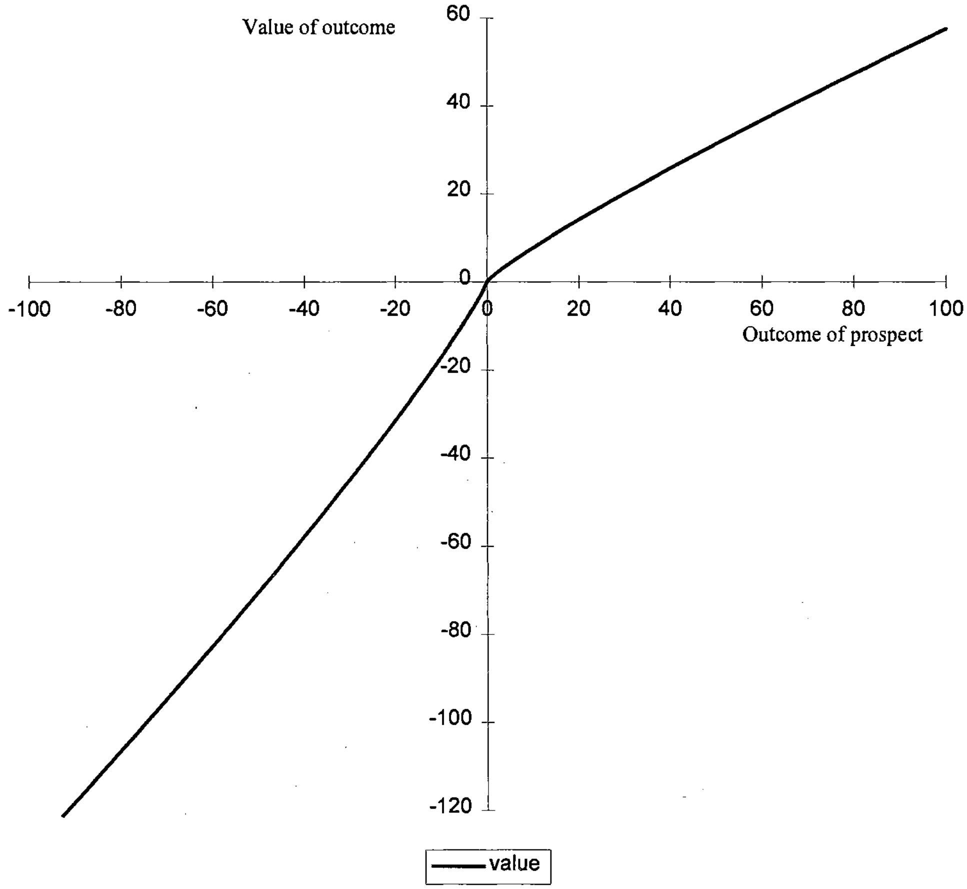
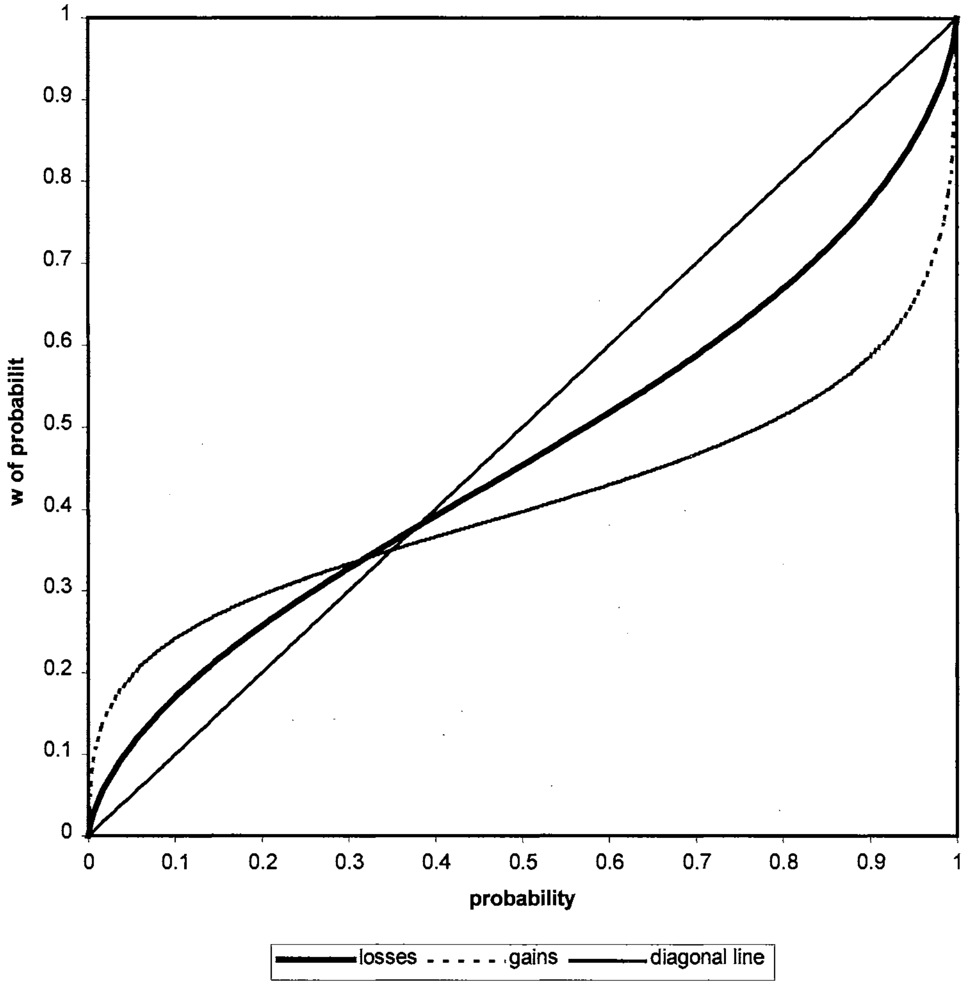


Figure 3. Weighting Functions for Gains and for Losses Based on Parameter Values Estimated by Tversky and Kahneman



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Chapter II

THE EFFECTS OF A NONLINEAR COST STRUCTURE ON ELEVATOR QUALITY DISCOUNTS FOR WHEAT

THE EFFECTS OF A NONLINEAR COST STRUCTURE ON ELEVATOR QUALITY DISCOUNTS FOR WHEAT

ABSTRACT

This study examined the effects of elevator cost structures on merchandising margins. The results suggest that elevator margins decrease slightly under the nonlinear cost structure as production in the elevator's trade area decreases while there is no change in margins under the linear cost structure. Elevators with nonlinear cost structures need to bid higher prices since reduced volume affects their costs more than it affects elevators with linear cost structures.

This results provide a partial explanation for elevators' reluctance to pay quality adjusted prices, since optimal price differences between high quality wheat and low quality wheat are always smaller under the nonlinear cost structure as quantity changes. Although the effect of a nonlinear cost structure was small for the parameters used here, a nonlinear cost structure may have a greater effect when combined with risk averse producers.

Key Words: nonlinear cost structure, merchandising margins, quantity changes

THE EFFECTS OF A NONLINEAR COST STRUCTURE ON ELEVATOR QUALITY DISCOUNTS FOR WHEAT

Introduction

In Chapter I, producers' risk attitudes were suggested as a possible reason that grain elevators are reluctant to pay quality-adjusted prices. In this part the effect of nonlinear cost structures is considered. Maintaining volume is an important factor in an elevator's operation, since the level of capacity utilization is directly related to the elevator's unit handling costs. The models used by Elliot et al. (1997, 1998) and Adam and Hong assumed that elevators have linear cost functions. In that case, only fixed cost is an important factor to capacity utilization. But, if elevators have nonlinear cost structures, variable cost is also affected by the volume of wheat handled.

Few studies of wheat elevator capacity utilization and cost structure exist. Thompson and Dziura found that merchandising margins in 1982 and 1983 at Illinois grain elevators were very sensitive to technical cost factors. They found an inverse relationship between the merchandising margin and scale of operation, radius of trade area, and capacity utilization.

Kenkel and Anderson estimated the cost of handling wheat in Oklahoma elevators. They found that average fixed costs per bushel are higher for elevators with annual throughput of 1,250,000 bushels of wheat handled per year than for elevators handling 650,000 bushels per year. However, variable costs decrease as elevator size moves from 650,000 to 900,000 bushels per year and then increase as size increases from 900,000 to 1,250,000 bushels per year.

As Table 1 indicates, they found that fixed costs account for more than 80 percent of total costs, a percentage that has greatly increased from 1983 to 1991. If elevators are operated at less than full capacity, fixed costs must be spread over a smaller volume. Hence, the elevators must bid higher prices to producers in order to maintain volume. This is consistent with the argument of Thompson and Dziura that lower merchandising margins are associated with greater capacity utilization.

Kenkel and Anderson contend that grain elevator managers who are considering a reduction in margins as a means of increasing volume must consider how competing firms will respond to this move. In the short run, reducing margins could be a viable strategy provided that variable costs are covered, but in the long run it may not be successful.

Some authors have examined the effects of cost structure on pork slaughter and processing firms' marketing strategies considering capacity utilization. Kambhampaty et al. found that double shift plants achieved lower per unit costs than single shift plants, and that per unit costs declined as capacity and capacity utilization increased. Hayenga found that the average and fixed processing costs per head decrease as plant size increases. These cost structures give useful implications for the growth of larger plants and larger firms, short term packer procurement strategy, market price behavior, and the shift away from the spot market as the primary coordination mechanism linking producers and packers (Hayenga). Since maintaining volume is important for elevators also, examining the effects of cost structure in grain elevators could also suggest implications for alternate marketing organizations such as vertical integration or coordination. The objective of this paper is to determine the extent to which nonlinear cost functions explain elevators' apparent reluctance to pay quality-adjusted prices for grain.

Conceptual Framework

In Chapter I, the effects of the price paid to farmers on an elevator's profit was considered assuming a linear cost structure. Chapter II analyzes its effect assuming a nonlinear cost structure. For simplicity it is assumed that quantity purchased from farmers is a function of price paid to farmers (p_f) and several parameters, such as the density of wheat production in an elevator's trade area (k), transportation cost (t), and an alternative outlet price (P_{ALT}) for a wheat producer. In this case the quantity of grain sold by farmers to an elevator can be expressed as

(1) $$Q = k[\pi(\frac{P_f - P_{ALT}}{t})^2].$$

All grain is assumed to be taken out of storage at the end of a period, so beginning and ending inventory is zero, and quantity purchased by the elevator equals quantity sold by the elevator. Therefore, the elevator's profit objective with a nonlinear cost function can be written as

(2) $$\pi = P_R Q(P_f) - P_f Q(P_f) - C[Q(P_f)],$$

where P_R = price received from NIL buyers, and C = total merchandising costs.

The profit function is non-increasing in costs of the elevator. The elevator maximizes profit by choosing P_f so that marginal revenue equals marginal cost. The first order condition for an elevator's profit maximization problem is

$$(3) \qquad \frac{\partial \pi}{\partial P_f} = P_R \frac{\partial Q(P_f)}{\partial P_f} - [P_f \frac{\partial Q(P_f)}{\partial P_f} + Q(P_f) + \frac{\partial C}{\partial Q(P_f)} \frac{\partial Q(P_f)}{\partial P_f}] = 0, \text{ or}$$

$$(4) \qquad P_R \frac{\partial Q(P_f)}{\partial P_f} = [P_f \frac{\partial Q(P_f)}{\partial P_f} + Q(P_f) + \frac{\partial C}{\partial Q(P_f)} \frac{\partial Q(P_f)}{\partial P_f}].$$

The condition says that price paid to farmers is chosen so that the additional revenue gained by raising price paid to farmers is equal to the additional cost incurred. Rewriting equation (3),

$$(5) \qquad \frac{\partial \pi}{\partial P_f} = [P_R - P_f - \frac{\partial C}{\partial Q(P_f)}] \frac{\partial Q(P_f)}{\partial P_f} - Q(P_f) = 0.$$

In order to satisfy the first order condition, the first term of equation (5) should be positive, since the first derivative of quantity with respect to price paid to farmers is positive. The second-order condition for profit maximization is

$$(6) \qquad \frac{\partial^2 \pi}{\partial P_f^2} = -\frac{\partial Q(P_f)}{\partial P_f}[2 + \frac{\partial Q(P_f)}{\partial P_f} \frac{\partial^2 C}{\partial Q(P_f)^2}] + [P_R - P_f - \frac{\partial C}{\partial Q(P_f)}] \frac{\partial^2 Q(P_f)}{\partial P_f^2} < 0.$$

The second-order condition holds if $\partial^2 Q(P_f) / \partial P_f^2 < 0$ and $\partial^2 C / \partial Q(P_f)^2 \geq 0$. Compared to the linear case, $\partial^2 C / \partial Q(P_f)^2$ is a new part. If the nonlinear cost function is quasi-convex, $\partial^2 C / \partial Q(P_f)^2 \geq 0$ is fulfilled.

A quadratic function is introduced as a specific case of nonlinear cost function. A positive coefficient of the second order term always satisfies the second order condition. Consider $C = a + bQ$ as a representative linear cost function and $C = \alpha + \beta Q + \gamma Q^2$ as a representative nonlinear cost function. To satisfy desirable conditions of cost functions, all parameters should be positive. Using these cost functions and equations (1) and (2), some derivatives are derived to distinguish the differences between these functional forms (Table 2). Depending upon the magnitudes of parameters and price paid to farmers, these derivatives might have different implications.

For comparing the linear and nonlinear cases, the two cost specifications are normalized. At the optimal quantity their marginal costs are the same and their average total costs are tangent to each other. If the first term of the quadratic cost function is positive, this function satisfies the optimization conditions. In Figure 1, total costs, marginal costs, and average total costs are the same for each cost structure at the optimal quantity, Q^*.

Suppose that some event, such as bad weather, causes the quantity of wheat in the elevator's trade area to decrease. As a result, the quantity purchased by the elevator at the original price shifts left to Q_1. Then the ATC of the firm with a quadratic cost structure increases more than that of a firm with a linear cost structure. Such a firm might have more incentive to pay a higher price to farmers to maintain volume. In such a case, elevators may have a disincentive to pay quality-adjusted prices to farmers, if they believe that they will be able to purchase less wheat.

To achieve a greater degree of consistency with observed elevator cost structures (e.g. Kenkel and Anderson), a higher fixed cost was used, so marginal costs and average costs (but not total costs) are the same for each cost structure. Since this study focuses on the effect of changes in volume on elevator's costs, and thus prices, rather than on the magnitude of costs themselves, this should not affect the validity of the analysis. The marginal and average cost structures used in this chapter are shown in Figure 2.

Procedure

The procedure is similar to the elevator optimization problem in part one except for using the quadratic cost function instead of linear cost function. For normalization, it is assumed that the optimal quantity is 2,700,000 bushels for elevators' profit maximization (which is near the optimal quantities determined in Chapter I for elevators A and B). In this case, the hypothesized functional form for a quadratic cost function is:

(7) $$C = 190000 + 0.0005085q + 0.00000001236q^2$$

and for a linear cost function is

(8) $$C = 100587 + 0.067q\,.$$

These two functions are shown in Figure 2.

With those two different cost structures, the objective functions of elevators' profit maximization problem are changed as follows for a nonlinear cost function without the producer's utility constraints:

(9) $$\underset{P_i^A}{\text{Max}}\, \mathit{Profit} = \sum_{i=1}^{n} [P_{NIL_i} - P_i^A] Q_i^A - 131400 + 0.1203 Q^A - 0.000000162 11 (Q^A)^2$$

subject to

(10) $$Q_i^A = k_i[\pi(D_i^A)^2]\text{, for all } i$$

(11) $$D_i^A = [\frac{1}{2t_i}(P_i^A - (P^B - t_i D))]\text{, for all } i$$

Elevator B:

(12) $\underset{P^B}{\text{Max}}\, Profit = \sum_{i=1}^{n}[P_{NIL_i} - P^B]Q_i^B - 131400 + 0.1203Q^B - 0.00000016211(Q^B)^2$

subject to

(13) $$Q_i^B = k_i[\pi(D_i^B)^2]\text{, for all } i$$

(14) $$D_i^B = [\frac{1}{2t_i}(P^B - (P_i^A - t_i D))]\text{, for all } i$$

(15) $$D = D_i^A + D_i^B = 40\text{, for all } i$$

and Q^A is the total amount of elevator A, and Q^B is the total amount of elevator B. In the case of a linear cost function, the cost part of the nonlinear case is replaced by the linear cost function.

In order to see the effect of changed quantity in the elevators' trade area, three different average wheat productions per square mile are assumed while optimizing elevator's profit. These average production amounts are arbitrarily chosen but represent a 25% increase and a 25% decrease from the original value assumed for wheat production, 2,174 bushels per square mile.

Results

The results of the analysis are presented in Tables 3 and 4. Table 3 reports the analytical solutions for elevator profit maximizing problem assuming different proportions of wheat quality (0.1, 0.6, 0.3 for high, middle, and low quality respectively). Under the linear cost structure, optimal prices paid to farmers do not change as production changes. This results from the elevator's constant marginal costs. With a nonlinear cost structure, however, optimal prices paid to farmers vary inversely with average production per acre. At lower levels of production, elevators A and B pay slightly higher prices. As higher levels of production, both elevators pay lower prices. Because of the increasing marginal cost curve, when the volume handled by an elevator decreases, marginal cost also decreases. Therefore, elevator managers can bid higher prices to farmers. The reverse is true as well. Also, as shown in Figures 1 and 2, average costs for the quadratic case increase more than they do in the linear case when volume decreases. This implies that the elevator with a quadratic cost structure has more pressure to maintain volume than one with a linear cost structure. Therefore, decreasing volume motivates the elevator manager to pay higher prices to farmers.

Table 4 shows the analytical solutions for the elevator profit maximization problem assuming equal proportions of each wheat quality (1/3 for whole qualities). Most figures in Table 4 have the same implications as Table 3. The optimal prices for the linear cost case are invariant for different average productions per acre, and the optimal prices for the quadratic case vary inversely with production. Comparing Tables 3 and 4 indicates that, under the quadratic cost structure, a smaller quantity available of a particular quality of wheat results in a higher price for wheat of that quality. For example, under the nonlinear cost structure when 1/3 of the average production of 2,174 bu./sqare mile is high quality, Elevator A pays $ 4.7153. When only 1/10 of the production is high quality, Elevator A pays $ 4.7206. This is not true under the linear cost structure. A second result is that under a nonlinear cost structure, there is slightly less incentive for elevator A to bid quality adjusted prices to producers as average production per acre changes. This result happens because departures from the minimum average cost point result in cost pressure to the elevator with the quadratic cost structure.

The results in Tables 3 and 4 also suggest that under the nonlinear cost structure elevators have more incentive to secure a larger quantity of wheat compared to elevators under the linear cost structure. In Table 4, as average production decreases by 25%, the profit of elevator A decreases by $165,000 and the profit of elevator B decreases by $141,000 under the linear cost structure. Under the nonlinear cost structure, the profit of elevator A decreases by $176,000 and the profit of elevator B decreases by $156,000 as the average amount decreases. Both are bigger decreases than under the linear case. A similar pattern is shown when the average amount increases. Maintaining volume is more important for elevators that have a nonlinear cost structure. Therefore, elevators might think of an alternative marketing strategy such as vertical coordination or contracts with farmers as expected production decreases.

It should be noted, however, that the differences in prices resulting from the nonlinear cost structure were quite small (e.g. the increase in Elevator A's price for high quality wheat increased by less than one cent per bushel as production decreased by 25%). The small effect may be related to the particular parameters chosen.

Conclusions

This study examined the effects of elevator cost structures on merchandising margins. The results suggest that elevator margins decrease slightly under the nonlinear cost structure as production in the elevator's trade area decreases while there is no change in margins under the linear cost structure. Elevators with nonlinear cost structures need to bid higher prices since reduced volume affects their costs more than it affects elevators with linear cost structures.

This study gives a possible explanation about why elevators pay less quality adjusted prices, since price gaps between high quality wheat and low quality wheat are always smaller under the nonlinear cost structure as quantity changes. Although the effect of a nonlinear cost structure was small for the parameters used here, a nonlinear cost structure may have a greater effect when combined with risk averse producers, or with different parameter specification.

Table 1. 1991 Up-Date Grain Handling Costs (cents/bu.)

Elevator Size(bu)	650,000	900,000	1,250,000	1983 Average
Total Fixed Costs	14.53	14.60	16.51	2.76
Total Variable Costs	4.05	2.56	5.89	7.20
Total Costs	18.57	17.16	22.40	9.96

Note: Source from Kenkel and Anderson (1992).

Table 2. Derivatives from Two Different Cost Structures: Linear and Quadratic Forms

	Linear case	Nonlinear case
$\partial TR/\partial P_f$	$[2P_R k\pi(P_f - P_{ALT})]/t^2$ (same for both cases)	
$\partial NR/\partial P_f$	$\{[2P_R k\pi(P_f - P_{ALT})]/t^2\}(P_R - P_f) - Q(P_f)$ (same for both cases)	
$\partial C/\partial Q$	$P_f + b$	$P_f + \beta + 2\gamma Q$
$\partial C/\partial P_f$	$[2k\pi(P_f - P_{ALT})/t^2](P_f + b) + Q(P_f)$	$[2k\pi(P_f - P_{ALT})/t^2][P_f + \beta + 2\gamma k\pi(P_f - P_{ALT})^2/t^2] + Q(P_f)$

Table 3. Analytical Solutions for Elevator Profit Maximization Problem Assuming Different Proportion of Wheat Quality(0.1,0.6,0.3) and Different Average Production Per Square Mile

Average Production Per Square Mile		Linear Cost Structure						Nonlinear Cost Structure					
		Elevator A			Elevator B			Elevator A			Elevator B		
		Quality of Wheat			Quality of Wheat			Quality of Wheat			Quality of Wheat		
		High	Mid.	Low	High	Mid.	Low	High	Mid.	Low	High	Mid.	Low
2,174 bu.	Price	4.6712	4.6045	4.5378	4.5875	4.5875	4.5875	4.7206	4.6325	4.5829	4.6231	4.6231	4.6231
	Dist.	23.8	20.8	17.7	16.2	19.2	22.3	24.4	20.4	18.2	15.6	19.6	21.8
	Q	387K	1768K	645K	179K	1515K	1015K	408K	1710K	677K	166K	1570K	976K
	Profit	531K			481K			483K			436K		
1,630 bu.	Price	4.6712	4.6045	4.5378	4.5875	4.5875	4.5875	4.7250	4.6420	4.5884	4.6309	4.6309	4.6309
	Dist.	23.8	20.8	17.7	16.2	19.2	22.3	24.3	20.5	18.1	15.7	19.5	21.9
	Q	290K	1326K	484K	134K	1136K	761K	302K	1292K	501K	127K	1168K	739K
	Profit	373K			335K			307K			271K		
2,718 bu.	Price	4.6712	4.6045	4.5378	4.5875	4.5875	4.5875	4.7162	4.6231	4.5773	4.6152	4.6152	4.6152
	Dist.	23.8	20.8	17.7	16.2	19.2	22.3	24.6	20.4	18.3	15.4	19.6	21.7
	Q	484K	2211K	806K	224K	1894K	1269K	516K	2123K	856K	203K	1977K	1209K
	Profit	689K			626K			665K			606K		

Note: 1. Functional form of linear cost structure is $C = 100587 + 0.067Q$.

2. Functional form of nonlinear cost structure is $C = 190000 + 0.0005085Q + 0.00000001236Q^2$.

Table 4. Analytical Solutions for Elevator Profit Maximization Problem Assuming Same Proportion of Wheat Quality (1/3, 1/3, 1/3) and Different Average Production Per Square Mile

Average Production Per Square Mile		Linear Cost Structure						Nonlinear Cost Structure					
		Elevator A			Elevator B			Elevator A			Elevator B		
		Quality of Wheat			Quality of Wheat			Quality of Wheat			Quality of Wheat		
		High	Mid.	Low	High	Mid.	Low	High	Mid.	Low	High	Mid.	Low
2,174 bu.	Price	4.6762	4.6096	4.5429	4.6027	4.6027	4.6027	4.7153	4.6533	4.5906	4.6471	4.6471	4.6471
	Dist.	23.3	20.3	17.3	16.7	19.7	22.7	23.1	20.3	17.4	16.9	19.7	22.6
	Q	1240K	939K	680K	632K	883K	1175K	1215K	936K	692K	650K	885K	1159K
	Profit	557K			464K			495K			408K		
1,630 bu.	Price	4.6762	4.6096	4.5429	4.6027	4.6027	4.6027	4.7221	4.659	4.5954	4.6526	4.6526	4.6526
	Dist.	23.3	20.3	17.3	16.7	19.7	22.7	23.1	20.3	17.4	16.9	19.7	22.6
	Q	930K	704K	510K	474K	662K	881K	915K	703K	517K	484K	663K	872K
	Profit	392K			323K			319K			252K		
2,718 bu.	Price	4.6762	4.6096	4.5429	4.6027	4.6027	4.6027	4.7086	4.6476	4.5859	4.6416	4.6416	4.6416
	Dist.	23.3	20.3	17.3	16.7	19.7	22.7	23.0	20.3	17.5	17.0	19.7	22.5
	Q	1551K	1174K	850K	790K	1103K	1469K	1512K	1170K	869K	818K	1108K	1445K
	Profit	722K			606K			676K			567K		

Note: 1. Functional form of linear cost structure is $C = 100587 + 0.067Q$.

2. Functional form of nonlinear cost structure is $C = 190000 + 0.0005085Q + 0.00000001236Q^2$.

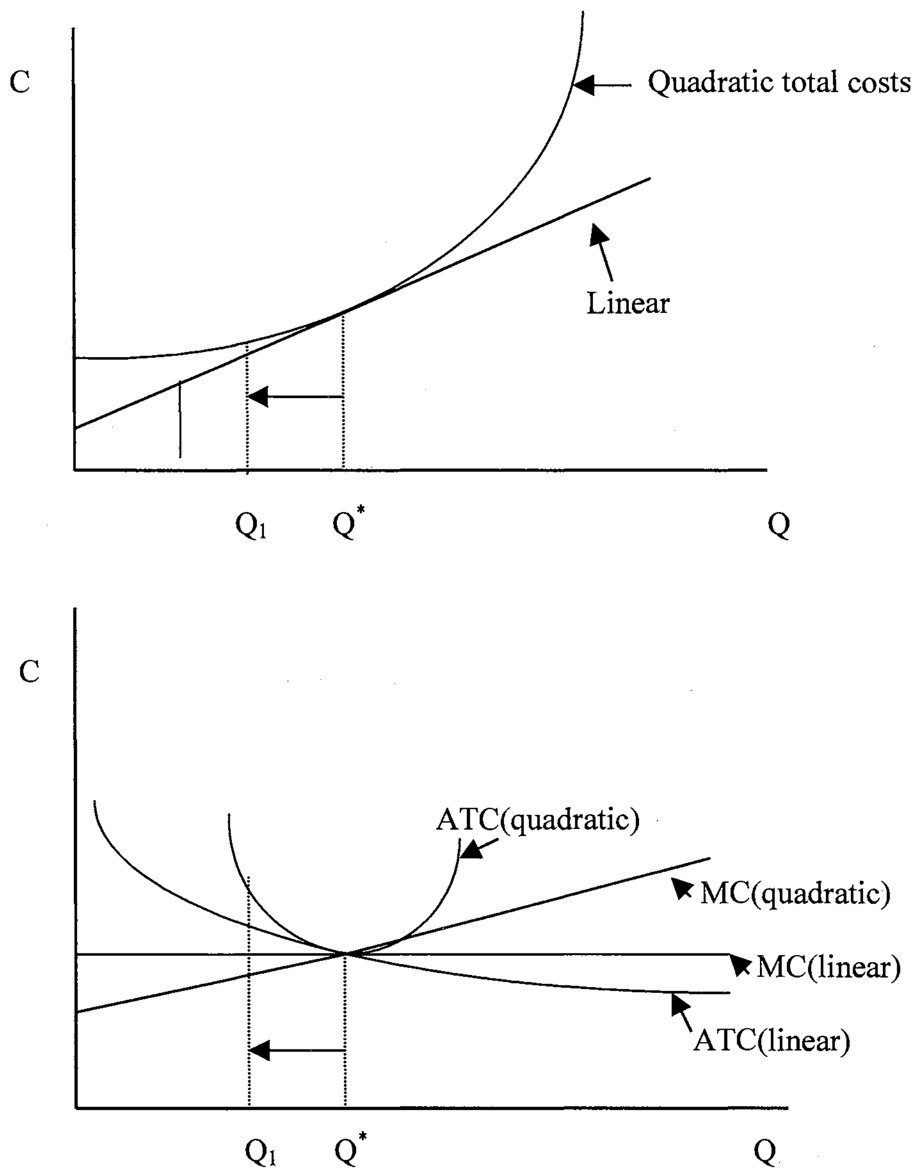

Figure 1. Linear and Quadratic Cost Functions

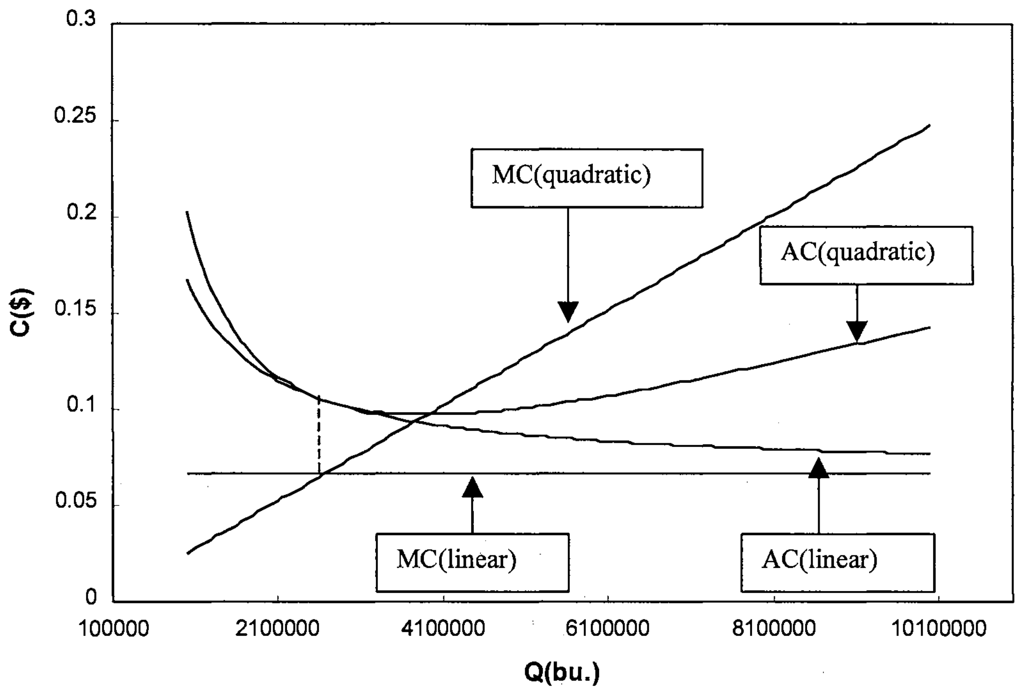

Figure 2. Graphical Representation of Marginal Cost Curves and Average Cost Curves for Linear and Quadratic Cost Structures Used in Analysis

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Chapter III

THE EFFECTS OF THE CONSERVATION RESERVE PROGRAM ON ELEVATOR MERCHANDISING MARGINS IN OKLAHOMA

THE EFFECTS OF THE CONSERVATION RESERVE PROGRAM ON ELEVATOR MERCHANDISING MARGINS IN OKLAHOMA

ABSTRACT

The study in this chapter determined the impact of the Conservation Reserve Program (CRP) on elevator merchandising margins in Oklahoma. It is hypothesized that this program, as well as the shorter-term Acreage Reduction Program (ARP), has had a negative effect on elevator margins by reducing harvested acres and wheat production. The impact on wheat production has not been proportional to the reduction in acreage, possibly due to slippage and wear-out effects. Since the effect differs across years, the overall effect of CRP on elevator margins is not clear. However, ARP has had a negative impact on margins.

Key Words: Conservation Reserve Program, margins, slippage effects, wear-out effects

THE EFFECTS OF THE CONSERVATION RESERVE PROGRAM ON ELEVATOR MERCHANDISING MARGINS IN OKLAHOMA

Introduction

The Conservation Reserve Program (CRP) is a voluntary, long-term land retirement program that was established under Title XII (Conservation Title) of the Food Security Act of 1985. The legislation was passed in a period of rising agriculture surpluses and increased concern over the on-site costs and off-site damage of soil erosion (Dicks and Coombs, 1994). It was designed specifically to assist landowners in protecting their most highly erodible cropland. This program, which affects land use, impacts the quantities of goods and services purchased for production activities and expended for marketing activities. The size of the potential impacts increases as the importance of agriculture in the economy increases.

Farm price and income stabilization along with environmental problems were major concerns as the CRP was designed. Through the CRP, production surpluses could be reduced while also dealing with environmental concerns by targeting cropland with highly erodible soils. Acreage enrollment in the CRP was geographically concentrated. Twenty-five percent of the countries with land enrolled in the CRP contained nearly 80 percent of the total program acreage. In addition, more than 40 percent of the land came from farmers that enrolled more than 80 percent of their cropland into the CRP (Dicks and Coombs, 1994).

This resulted in a concentration of economic impacts on regional economies (Hyberg, Dicks, and Hebert). For example, under the first 9 sign-up periods (March 1986 to 1990) the CRP reduced the available acreage of wheat by 10 million acres. This resulted in an estimated reduction of 288 million bushels of wheat produced per year (USDA, 1994). This decrease in production led to increase competitive pressures and may have adversely affected many Great Plains agribusiness firms. CRP enrollment in October 1998 exceeded 29.8 million acres and about two-thirds of this land had a crop base history. Half of this land came from areas that produced wheat while 18 percent came from corn. Much of this acreage resided in the Northern and Southern Plains regions. The Northern Plains region consists of Kansas, Nebraska, North Dakota, and South Dakota which contains 8.2 million acres in the CRP. The Southern Plains includes Oklahoma and Texas and has 4.6 million acres enrolled (USDA, 1999).

Although much research has attempted to evaluate the environmental and budgetary impacts of CRP, little research has examined the impacts on agribusiness firms. A study by Hyberg, Dicks, and Hebert (1991) indicated that the CRP had only minor impacts nationally and regionally, but reduced economic activity by as much as 20 percent in areas with high enrollment. These impacts were directly attributable to the reduced output associated with land idled under the program. However, that study did not consider the impacts of the program on merchandising margins, which may have changed as a result of the reduced levels of production.

Many elevator managers, particularly those in areas with high CRP participation, believe that CRP has contributed substantially to their financial stress. In Oklahoma, for example, CRP enrollment for several counties exceeds 25 percent of the total cropland in the county. Hence, the impacts of the CRP may have contributed to the declining profits and tight margins for several grain elevators in the state over the past few years.

However, this belief has not been confirmed strongly as historical relationship between merchandising margins and wheat yields is considered. Figure 1 shows the trends of wheat yields and merchandising margins and figure 2 shows the trends among CRP enrollment acres, wheat planted acres, and harvested acres of Blaine County[1] in Oklahoma from 1979 through 1998. In Figure 1, it is not clear that wheat production and margins are positively correlated. Similarly, the relationship among CRP acres, planted acres, and harvested acres is not strong (Figure2). These phenomena suggest the possibility that the effect of CRP on wheat yields may not have contributed much to the declining profits and tight margins for wheat elevators.

Although many factors have contributed to the problems facing grain elevators, such as reduced grain exports, heavy borrowing and expansion in the late 1970s and early 1980s, as well as the overall weak farm economy, the evaluation of the effects of the CRP will provide useful information as the CRP's future is debated.

This paper focuses on the effect of CRP on elevator profits by assessing the impacts of CRP on elevator merchandising margins in Oklahoma. Also, this paper considers the related elevator pricing rules since these pricing rules may affect the elevator's merchandising margins.

A theoretical model is developed for grain elevators performing grain merchandising services. Comparative static analysis shows the expected effect of land retirement programs on elevator merchandising margins. Empirical models are used to

[1] Blaine County includes 3 elevators out of 15 in the sample used here. State level data shows a similar pattern.

identify pricing rules elevators use and then to assess the impacts of CRP on grain elevator margins in major wheat-producing counties in Oklahoma.

Theoretical Framework

Consider a competitive elevator providing one service, merchandising, where grain purchased from farmers is sold directly to next-in-line (NIL) buyers. That is, all grain must be taken out of storage at the end of the period, so beginning and ending inventory is zero, and quantity purchased by the elevator equals quantity sold by the elevator. The elevator's profit objective can be written as

(1) $$\pi = P_R Q - P_f Q - C_v Q - C_{fx},$$

where P_R is a price received from NIL buyers, P_f is a price paid to farmers, C_v is variable merchandising costs, C_{fx} is fixed costs, and Q is quantity purchased from farmers and sold to NIL buyers.

Quantity of grain purchased from farmers can be expressed as:

(2) $$Q = Q(P_f, I(G, N), S).$$

The quantity of grain sold by farmers to an elevator (Q) depends on the price paid to farmers for the grain (P_f), the relative incentives for the producer to store or sell the grain at harvest and for the elevator to attract grain from storage, represented by S, and the intensity of production (I) in the area surrounding the elevator. The intensity of production is a measure of the amount of grain produced on the land surrounding the elevator. Within a crop year, the intensity of production is dependent on government farm program variables (G), and other variables, represented by N, such as weather and local supply as well as demand conditions. The quantity purchased from farmers also depends on bid prices of competing elevators. Thus, the quantity of wheat purchased by the elevator is positively related to the price paid by the elevator, and to the density of production, but negatively related to competitors' prices and transportation cost. Rewriting (1), the elevator's profit can be expressed as

(3) $$\pi = P_R Q - [P_f Q + C_v Q + C_{fx}].$$

Assuming that the elevator practices marginal cost pricing, the elevator maximizes profit by choosing P_f so that marginal revenue equals marginal cost since the elevators have spatial monopsonic power in input market. This assertion is based on the assumption that the elevator uses a marginal cost pricing rule:

(4) $$\frac{\partial \pi}{\partial P_f} = P_R \frac{\partial Q}{\partial P_f} - [P_f \frac{\partial Q}{\partial P_f} + Q + C_v \frac{\partial Q}{\partial P_f}] = 0, \text{ or}$$

(5) $$P_R \frac{\partial Q}{\partial P_f} = [P_f \frac{\partial Q}{\partial P_f} + Q + C_v \frac{\partial Q}{\partial P_f}].$$

The condition says that price paid to farmers is chosen so that the additional revenue gained by raising price paid to farmers is equal to the additional cost incurred.

Solving equation (5), the elevator's optimal purchase price for grain is

(6) $$P_f^* = P_f^*(P_{R,} I(G,N), S, C_v).$$

To increase the amount of grain handled, the elevator must increase its market area by increasing bids to farmers (Bressler and King, 1978, p. 128ff). Price received is assumed given, so changes in price bids to farmers, P_f, directly affect merchandising margins. Taking the partial derivative of (4) with respect to I and using (6) results in the following relation:

$$(7) \qquad \frac{\partial P_f^*}{\partial I} = \frac{\dfrac{\partial Q}{\partial I}}{-2\dfrac{\partial Q}{\partial P_f^*} + [P_R - P_f^* - C_v]\dfrac{\partial^2 Q}{\partial P_f^{*2}}} < 0,$$

provided that the second term in the denominator is small or negative, and that second order conditions hold. As intensity of production in the area surrounding the elevator increases, price bid to farmers will decrease, increasing elevator merchandising margins.

Pricing Rule

The above analysis assumes that elevators practice marginal cost pricing. However, if elevators are not competitive in the input market, then they might use average cost pricing instead of marginal cost pricing. Under this strategy, elevators establish a bid price by subtracting average cost from the price received from NIL buyer. If an elevator follows this pricing strategy, when quantity of wheat in its trade area is reduced, the elevators will bid a lower price to producers, and its margins will increase.

The other strategy, which is identified in the previous section, is a pricing rule based upon the structure-conduct-performance (SCP) paradigm. Under this pricing rule (marginal cost pricing) an inverse relationship exists between competition in factor markets and the number of firms (Bain). If an elevator follows a SCP pricing rule, when quantity of wheat is reduced, the elevator would bid a higher price to producers, and margins would decrease. Stiegert, Azzam, and Brorsen (1993) examined how a markdown[2] is affected by anticipated and unanticipated supply to infer fed cattle pricing strategies used by packers. For this purpose, they estimated anticipated and unanticipated fed cattle supply, and specified three possible relationships among the markdown, anticipated supply, and unanticipated supply. Their method is adopted to examine how the margin is affected by anticipated and unanticipated wheat production changes in Oklahoma wheat elevator industry, and which pricing rule is more appropriate to explain Oklahoma elevator pricing practices.

In order to generate anticipated and unanticipated wheat production, the following yield equation is estimated using time series data in 15 elevator regions in Oklahoma:

(8) $$y_{it} = b_0 + b_1 lp_{it} + b_2 ARP\%_t + b_3 CRP\%_{it} + b_4 n_{it} + b_5 Time + y_{uit},$$

where y_{it} is wheat production in the *i*th elevator region in year t , lp_{it} is bid price of elevator in the *i*th elevator region in year t-1, n_{it} is amount of nitrogen used for wheat production in the *i*th elevator region in year t-1, $ARP\%_t$ is acreage reduction program percentage in year t-1, $CRP\%_{it}$ is conservation reserve program participating percentage in the *i*th elevator region in year t-1 compared to base year (1980) acres, and y_{uit} is an error term and assumed to have white-noise properties. y_{uit} represents unanticipated wheat production, and is used to measure y_{ait}, anticipated wheat production, by subtracting y_{uit} from y_{it}.

The margin is specified as:

(9) $$m_{it} = f(y_{ait}, y_{uit}, Time),$$

where *Time* is a time trend to capture other factors such as technological change.

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[2] In their article, they defined markdown as a gap between the price of fed cattle and its marginal value product.

In order to examine elevators' response to anticipated production and to unanticipated production, three different models are used, each with a different specification of the unanticipated production. The first specification is linear in unanticipated production:

$$(10) \qquad m_{it} = c_0 + c_1 y_{ait} + c_2 Time + c_3 y_{uit} + \varepsilon_{it}.$$

The second specification is quadratic in unanticipated production:

$$(11) \qquad m_{it} = c_0 + c_1 y_{ait} + c_2 Time + c_3 y_{uit} + c_4 y_{uit}^2 + \varepsilon_{it}$$

and the third specification is cubic in unanticipated production:

$$(12) \qquad m_{it} = c_0 + c_1 y_{ait} + c_2 Time + c_3 y_{uit} + c_4 y_{uit}^2 + c_5 y_{uit}^3 + \varepsilon_{it}.$$

The coefficients in equation (10)-(12) can indicate which pricing rule is prevalent among wheat elevators in Oklahoma and how wheat supply reduction due to CRP is expected to affect the elevator merchandising margins.

Following Stiegert et al., for all three specifications, $c_1 > 0$ is consistent with SCP pricing in anticipated wheat production, and $c_1 < 0$ is consistent with AC pricing in anticipated wheat production. The result $c_3 > 0$ is consistent with SCP pricing, which implies the margins decreases (increases) when unanticipated supply is negative (positive).

However, in some cases, a combination of the two pricing rules is possible. When c_1 is greater than zero and c_3 is less than zero, elevators could maintain either SCP pricing or AC pricing depending on the relative magnitude of the anticipated production and the unanticipated production. If unanticipated wheat production is small, then SCP pricing rule will be prevalent. Otherwise, the AC pricing rule will be prevalent.

The quadratic specification is introduced to see if markdowns increase or decrease when unanticipated wheat production is positive or negative. The cubic specification is included to see other possible behavioral combinations.

Wear-Out Effects

Following Reberte et al., who modeled "wear-out" in an advertising campaign, the model is specified to allow the effects of CRP to diminish over time. A hypothesized wear-out effect reflects a belief that the effectiveness of an advertising campaign will eventually decay. Similarly, if the supply of wheat in an elevator's trade area is reduced, and the elevator anticipates that the effect is relatively permanent (e.g., CRP contracts typically last 10 years), it can adjust its cost structure to match its expected lower volume of grain purchases. In effect, the elevator can move back along its average cost curve from one short-run average cost curve to another that reaches a minimum at a lower volume of production. For example, it can re-negotiate lower shipment volumes in railroad contracts that call for a minimum amount of grain to be shipped within a certain period of time, remove part of its merchandising capacity from service, or reduce the number of salaried employees. Decreasing the volume of grain required to efficiently operate the elevator would allow it to reduce bids to producers, increasing its merchandising margin.

To model this effect, following Reberte et al., the interaction variables $CRP\%_{it} * Time$ and $CRP\%_{it} * Time^2$ are included in the model. *Time* is a trend variable, made up of sequential integers from 1 in 1980 to 19 in 1998 for each elevator. A positive (negative) coefficient on the variable $CRP\%_{it} * Time$ would suggest that the effects on merchandising margins of a given percentage of CRP acres have increased (decreased) over time. A coefficient on $CRP\%_{it} * Time^2$ with sign opposite that of the coefficient on $CRP\%_{it} * Time$ would indicate that the strength of any interaction between $CRP\%_{it}$ and *Time* has tended to decrease over time; the same sign would indicate that the strength of any interaction has intensified over time. In addition, the *Time* variable by itself serves as a proxy for structural change occurring over this time period.

Data

Data used applied to fifteen elevators in ten counties in Oklahoma for the period 1980 through 1998 for the analysis of the impact of CRP on elevator merchandising margins. In order to calculate merchandising margins (m_{it}), two price series were used. One is P_{Rt}, which is the average of June daily prices received by Oklahoma elevators for wheat shipped to Gulf ports net of transportation costs. It is calculated as average Gulf price minus rail transportation rates from Gulf ports to central Oklahoma. The transportation rates were provided by an elevator in central Oklahoma. The other is lp_{it}, which is the average of June daily prices paid to producers by the elevators for hard red winter wheat. Merchandising margins are calculated as the difference between these two prices. These data were obtained from USDA and from various issues of Oklahoma market report from Oklahoma Agricultural Statistics.

To capture the effects of government land retirement programs on the intensity of wheat production in an elevator's trade area, CRP enrollment acreage and ARP set-aside data were collected. Data for the variable $ARP\%_t$ were obtained from the Farm Service

Agency, and represent the mandatory set-aside percent for government program participation. This represents the percentage of acres enrolled in government programs that cannot be used to grow program crops.

Acres participating in CRP in each year in the counties where the elevators are located were taken from the CRP contract file of USDA's Farm Services Agency. The $CRP\%_{it}$ variable represents the summation of incremental reductions in base acres due to enrollment in CRP, divided by the number of planted wheat acres in 1980. 1980 was chosen as a base year because there were no short term or long term land retirement government programs. Until 1987 there was no CRP, so the variable $CRP\%_{it}$ has zero values through 1986.

Other variables hypothesized to affect wheat production are amount of nitrogen fertilizer used and steer prices. Steer prices divided by July contract futures price on the first trading day of January gives a steer-wheat price ratio variable (sw_t)[3]. This variable affects the decision of farmers about which proportion of wheat planted acres are allocated to grazing or to wheat harvested for grain. These data were obtained from Livestock, Meat and Wool Weekly Summary and Statistics in Agricultural Marketing Service, and the Annual Report of the Kansas City Board of Trade. Nitrogen fertilizer amount (n_{it}) is expected to have a positive effect on wheat production. Nitrogen and wheat production data for each county were collected from Oklahoma Agricultural Statistics.

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[3] sw_t values are calculated by following formula: sw_t={[750*(steer price(cents per pound) for 750 pounds on Jan. 1)-550*(steer price(cents per pound) for 550 pounds on Jan.1)]/200}/(futures price of July contract on the first trading day of January ($/bu.))

Other factors can affect the merchandising margins of an elevator through a producer's choice between selling the grain or storing at harvest. An example of this is the expected return from storing wheat which is measured as the June 20 difference between the December Kansas City Board of Trade (KCBT) wheat futures price and the July KCBT wheat futures price. Another example of this is the amount of on-farm stocks. Variables mentioned above could affect the elevator bid prices, and thus the elevator's margins. But these effects may vary depending upon which pricing rule is used by an elevator manager. These data were obtained from Kansas City Board of Trade and Oklahoma Agricultural Statistics. Table 1 shows the variable notations, their descriptions, and units used in this chapter.

The Model

The impact of CRP on elevator merchandising margins can be examined directly using a model that regresses margins with regard to CRP along with other relevant factors. In addition, other models are specified to better understand the effects of CRP on wheat production and merchandising margins. For this purpose, four models are specified.

The first model is specified to see the effects of CRP on harvested acres. The harvested acres(ha_{it}) can be explained by *CRP%*, *ARP%*, lagged paid prices to farmers (lp_{it}) , steer-wheat price ratios (sw_{it}), and time trend variable to capture any technological change (*Time*).

The second model is specified to examine the effect of CRP on wheat production (y_{it}) along with the variables used for harvested acres estimation and nitrogen (n_{it}). This model is also used for estimating anticipated and unanticipated wheat production.

The third model estimates the relationship between margins (m_{it}) and wheat production (y_{it}). Other relevant variables are lagged margins in year t (lm_{it}), on-farm stock on June 1 in Oklahoma in year t ($onst_t$), and December-July contract futures price difference on June 20th in year t (dj_t) will be estimated. The interaction variables between y_{it} and *Time* are included to examine how margins have responded to the change of y_{it}.

Finally, a model is specified to estimate the direct effect of $CRP\%_{it}$ on margins. In order to test the Wear-Out effect, $CRP\%_{it}$ and *Time* interaction terms are also included.

The models are specified as follows:

(13) $$ha_{it} = f(sw_t, lp_{it}, CRP\%_{it}, ARP_t, t),$$

(14) $$y_{it} = f(lp_{it}, CRP\%_{it}, ARP_t, n_{it}, t),$$

(15) $$m_{it} = f(lm_{it}, y_{it}, t, y_{it}t, y_{it}t^2, onst_t, dj_t), \text{ and}$$

(16) $$m_{it} = f(lm_{it}, CRP\%_{it}, ARP\%_t, t, CRP\%_{it}t, CRP\%_{it}t^2, onst_t, dj_t).$$

The models are estimated with pooling cross-section and time-series observations (panel data), as in the case of observations for a number of elevators over several periods of time. In this case, the assumptions about the behavior of the disturbances are important, since a different estimation method will be appropriate for different disturbance specifications.

The models can be estimated using two approaches for allowing different intercept effects for each cross-section (Judge et al). One approach is to introduce dummy variables and estimate the parameters by OLS. A second is to estimate the parameters while assuming a random intercept to give an error components (SHAZAM). The first approach is reasonable when the differences between units can be viewed as parametric shifts of the regression function. But if sampled cross-sectional units are randomly drawn from a large population, it is more suitable to consider individual constant terms as randomly distributed across cross-sectional units (Green).

In order to select a proper model, a test for the existence of a random individual effect can be used. Both the fixed effect model and the error component model can be written as:

$$y_{it} = \overline{\beta}_1 + \mu_i + \sum_{k=2}^{K} \beta_k x_{kit} + e_{it} \,, \tag{17}$$

where i = 1, ..., N for individuals, and t = 1, ... , T for time trends. The disturbance term e_{it} and μ_i are assumed to have following properties: (a) $E(e_{it}) = 0$ and $E(\mu_i) = 0$, (b) $Var(e_{it}) = \sigma_e^2$ and $Var(\mu_i) = \sigma_\mu^2$, and (c) e_{it} have no autocorrelation, no heteroscedasticity, and no contemporaneous correlation.

In the fixed effect model the μ_i are treated as fixed parameters that need to be estimated, whereas in the error component model the μ_i are treated as a sample of random drawings from a population, and they become part of the model's disturbance term. If μ_i is equal to zero, or equivalently σ_μ^2 is equal to zero, the individual random components do not exist and the fixed effect model is preferred. The null hypothesis is $\sigma_\mu^2 = 0$ and the alternative is $\sigma_\mu^2 > 0$. The test is based on the Lagrange multiplier statistic which requires only the restricted residuals from OLS. Under the null hypothesis $\sigma_\mu^2 = 0$, the test statistic, λ, is aymptotically distributed as $\chi^2_{(1)}$, where e_{it} is the least squares residuals obtained by regressing dependent variable, y, on independent variables, $\boldsymbol{X}$ (Judge et al.).

(18) $$\lambda = \frac{NT}{2(T-1)}[(\sum_{i=1}^{N}(\sum_{t=1}^{T} e_{it})^2)/\sum_{i=1}^{N}\sum_{t=1}^{T} e_{it}{}^2 - 1]^2 .$$

If this statistic is not significant, it is concluded that the fixed effect model fits better than the error component model.

However, both the fixed effect and the error component model are valid when there is no heteroscedasticity among cross-sections or no autocorrelation over time periods in disturbances, e_{it}. Otherwise, both models are invalid for estimating the empirical models.

In general, when dealing with panel data a cross-sectionally correlated and time-wise autoregressive model (Kmenta Model) is usually adopted. The particular characterization of this model is as follows (Kmenta):

(19) $E(\varepsilon_{it}^2) = \sigma_i^2$ (heteroscedasticity),

(20) $E(\varepsilon_{it}\varepsilon_{jt}) = \sigma_{ij}$ (mutual correlation),

(21) $\varepsilon_{it} = \rho_i \varepsilon_{i,t-1} + u_{it}$ (autoregression).

Therefore Kmenta model makes it possible to add the individual and time-specific random effects to the error disturbances, and the parameters are efficiently estimated using the generalized least squares procedure.

For model selection, the Durbin-Watson or Durbin-*h* test statistics for autocorrelation and the Breusch-Pagan-Godfrey (B-P-G) test statistic for heteroscedasticity are checked with each empirical model. If relevant statistics are not significant, the Lagrange multiplier test will be implemented to test for the individual random effect.

Table 2 shows the results of the tests for heteroscedasticity and autocorrelation, and p-values for the test statistics are given in parentheses. In equation (14) and (15), the statistics for heteroscedasticity and autocorrelation are significant with p-values less than 0.0001, indicating that the Kmenta model is appropriate for estimating these two empirical models.

In equation (13), the B-P-G test statistic is 5.014 with a p-value of 0.414, which implies that there is no significant evidence of heteroscedastic disturbance. But, the D-W test statistic is 0.3645 with a p-value of 0.0001, indicating autocorrelation in disturbances.

In equation (16), the B-P-G test statistics is 26.639 and associated p-value is 0.0012, even the Durbin h statistic is not significant. Therefore, Kmenta model is employed in estimating equation (13) and (16) also.

In conclusion, empirical models are as follows and are estimated using the Kmenta model:

(22) $$ha_{it} = a_0 + a_1 sw_t + a_2 lp_{it} + a_3 CRP\%_{it} + a_4 ARP_t + a_5 t + e_{it}$$

(23) $$y_{it} = b_0 + b_1 lp_{it} + b_2 ARP\%_t + b_3 CRP\%_{it} + b_4 n_{it} + b_5 Time + e_{it}$$

(24) $$m_{it} = d_0 + d_1 lm_{it} + d_2 y_{it} + d_3 t + d_4 y_{it} t + d_5 y_{it} t^2 + d_6 onst_t + d_7 dj_t + e_{it})$$

(25) $$m_{it} = f_0 + f_1 lm_{it} + f_2 CRP\%_{it} + f_3 ARP\%_t + f_4 t + f_5 CRP\%_{it} t + f_6 CRP\%_{it} t^2 + f_7 onst_t + f_8 dj_t + e_{it})$$

where a's, b's, d's, and f's are coefficients and e_{it} is disturbance term.

Empirical Results

The estimated parameters of factors explaining wheat harvested acres are presented in Table 3. All parameter estimates are statistically significant at 5% significance level except time trend variable. About 55% of harvested acre variability is explained. In this empirical model, there are two price-related variables. The lagged price of wheat is assumed to be a proxy variable for producers' price expectations at planting time. The coefficient on this variable is expected to be positive, since high price expectation results in increase in planted wheat acreage, and thus harvested acreage. In Table 2, the parameter estimate of this variable has the highest effect on harvested acres. Almost 4,600 acres are harvested more as lagged paid price increases by one dollar.

Steer-wheat price ratio estimate is also significantly different from zero, and has negative effect on harvested acres. The producers' decision as to how many acres to be grazed or harvested has been usually made in January considering the wheat value and steer value. Higher values of this variable means the steer value has increased relative to the wheat value. Therefore, farmers will decide to use more planted wheat acreage for grazing instead of harvesting. The negative coefficient in steer-wheat prices ratio means that every $1/cwt. gain in steer price reduces harvested wheat by 1,368 acres.

Lagged CRP% variable has more negative impact on harvested acres compared to ARP% variable. Lagged ARP% variable also has negative parameter value, but the level of lagged ARP% is much smaller than that of lagged CRP%. The parameter value of Lagged CRP% is –2.1624, which implies that 1% increase of this variable reduces 2,162 harvested acres, and is almost two times large than the Lagged ARP% variable. This result indicates that the long-term land retirement program is more effective than the short-term land retirement program.

Table 4 shows the parameter estimates of the regression model for wheat production. All parameter values except the intercept are significantly different from zero at the 5% significance level, and 82% of wheat production variability is explained. Except for the Lagged ARP% variable, the variables have reasonable parameter values. First, the parameter values for Lagged Paid Price and Nitrogen amount have positive signs as expected. Because Lagged Paid Price has a positive effect on harvested acres (Table 3), it has a positive effect on wheat production. The coefficient of Lagged Paid Price indicates that a $1/bu increase in wheat price in year t-1 increases wheat production in year t by 331,070 bushels. An increase in nitrogen use by 1,000 tons increases production by 282,290 bushels; an increase of one ton of nitrogen increased production by 7 bushels of wheat. This is consistent with field trials in Oklahoma. The Lagged CRP% estimate indicates that one percentage increase in CRP% reduces production by 124,490 bushels.[4]

In table 4, the parameter estimate of Lagged ARP% is positive, although statistically insignificant. This variable has a negative impact on harvested acres in Table

[4] Lagged CRP and ARP are used because acres for a particular year (say 1996) affect planting in that year and are harvested in the following year (say 1997).

3, so it is natural to expect its effect on wheat production to also be negative. However, producers can devote less productive acres to ARP and concentrate their efforts as well as fixed resources on more productive acres since they know about the ARP% before they start to plant wheat.

This phenomenon is known as slippage effect (Love and Foster, 1990; Leathers and Harrington, 2000; Wu, 2000). Slippage represents the increased per-acre yields associated with government acreage control program. This term describes the frequently observed phenomenon that the level of commodity production decreases proportionately less than the number of acres idled in response to these programs.

Wu (2000) has identified two reasons for slippage effects. First, some non-cropland may be brought into production as a result of increased output prices associated with reduced production on retired land. Second, farmers may substitute other land for crop production because of scale economies and fixed input effects. In addition, farmers may use resources more intensively on remaining land, raising per-acre yield. The results in Table 4 suggest that slippage effects from ARP are larger than those from CRP, in that Lagged CRP% has a significant negative coefficient while the coefficient on Lagged ARP% is not statistically significant. This may be due to the lag between planting dates and the date ARP set-aside must be certified. In most years, wheat is planted and growing so that the farmer can identify the worst performing acres before they must actually be set aside.

Therefore, average yield per harvested acre could increase and so the level of wheat production decreases proportionately less than the number of acres idled in response to these programs. Slippage effects can be attributed to both ARP and CRP program, and it is not easy to tell which program has more contribution to slippage because both programs have coexisted in some data periods. Following the results of Table 4, it can be concluded that Lagged ARP% has more slippage than Lagged CRP% variable has.

The parameter estimates for the pricing models are shown in Table 5. For all three specifications, c_1 is greater than zero and significant. This implies that margins increase when anticipated wheat production increases. As evidenced by the Buse R^2 of 0.82 in Table 4, since anticipated wheat production accounts for 82% of wheat production variability, SCP pricing can be considered as the dominant pricing strategy. Time trend estimate (c_2) is negative and statistically significant indicating the improvement of technology has reduced margins over time. However, c_3 is less than zero and significant, and its absolute value is almost four times larger than c_1 for all three specifications. This implies that a large unanticipated wheat production can result in a change in the pricing rule to AC pricing.

In the quadratic specification, the estimate of c_4 is not significantly different from zero, so this specification does not give additional information about the pricing rule. In the cubic specification, the estimate of c_5 is greater than zero and significant, supporting SCP pricing. Therefore, this value supports SCP pricing. In conclusion, elevators respond to production shocks with a combination of pricing rules, maintaining SPC pricing rule as long as unanticipated wheat production is not large. However, it should be mentioned that this conclusion is less persuasive since only 40% of margins variability can be explained by the independent variables for the three models as evidenced by the Buse R^2 values in Table 5.

Table 6 shows the estimates of factors explaining merchandising margins using actual wheat production. All parameter estimates are statistically significant at 10% significance level except the time trend variable. The positive parameter value on Lagged Margins indicates that this year's margin is positively related to last year's margin. The wheat production parameter, 0.00544, implies that when wheat production increases by one million bushels, margins increase by 0.54 cents. This result corresponds to the hypothesis that more production induces a lower bid price to wheat farmers, in turn increasing margins.

Table 7 shows the estimates of factors explaining merchandising margins using ARP% and CRP% variables rather than wheat production itself. All parameter estimates are statistically significant at the 10% significance level. The positive parameter value of Lagged Margins indicates again that this year's margin is positively related to last year's margins. *CRP%*Time*, and $CRP\%*Time^2$ terms are included in the margins regression model to see the wear-out effects of CRP on merchandising margins over time. Using the results of Table 7, the marginal effect of CRP% on margins over time is expressed by equation (26):

$$(26) \qquad \frac{\partial Margins}{\partial CRP\%} = -0.0277 + 0.00536 * Time - 0.00022 * Time^2 .$$

Figure 3 plots the locus of derivative values from equation (26) over time.

In Figure 3 it is shown that the CRP effects on margins over time have been positive and increased during 1987 through 1991. However, CRP effects have been decreased after 1991, and after 1997 have been negative. This phenomenon supports the wear-out hypothesis, implying that CRP effects have decreased over time. This relationship may result from the adjustment ability of an elevator to adapt to new situations. Elevators likely faced pressure when CRP was introduced because of the reduced volume of wheat. But the results suggest that by 1991 they had started to adjust to their new environment.

The parameter values of ARP% and CRP% are negative as expected. Although the two estimates can not be compared directly because the percentages are calculated on different bases, the initial effects of CRP are roughly five times larger than the effects of ARP. This result supports results from Table 3 and 4 and the observation of Riddel and Skold (1997), that the longer-term CRP has had a bigger effect on wheat production than the shorter-term ARP.

The On-farm Stock variable has a positive sign, suggesting that elevator managers know that farmers will eventually sell their stocks so that elevator managers do not feel pressure to bid high prices to bring it to market. The coefficient on Dec.-July Spread is negative and significant. The higher the spread, the more incentive elevator managers have to bid higher prices to farmers to take advantage of the potential gains the spread offers from storage.

Because of the time interaction variables, understanding the effects on merchandising margins due to CRP is somewhat difficult. In order to better understand these results, several comparisons using estimates from Table 7 are made. The estimated coefficients are used to "predict" merchandising margins assuming first that CRP acres are set to the values that were observed in the data, and then that CRP acres are set to equal zero. Thus, the figures provide insight into the effects over time that CRP has had.

Figure 4 predicts merchandising margins for each of the 15 elevator regions using values for the independent variables that are the averages of these variables across the entire time period. Predicted margins using observed average CRP enrollment are actually higher than predicted margins with CRP set equal to zero. This result is opposite what was hypothesized. However, Figure 5 indicates that when predictions are made for each year using averages across the 15 elevator regions, predicted margins are lower with CRP average values than when CRP is set equal to zero for the years 1987-1989 and then again in 1991, but higher for the other years.

Figure 6 through 9 show predictions for each elevator region for each of four different years, using observed values for the independent variables for each year and each elevator region. As with Figures 4 and 5, predictions setting CRP equal to its observed value are compared with predictions setting CRP equal to zero. Figures 6 through 8 show that for the years 1988, 1992, and 1995 predictions margins are higher with observed CRP values than with CRP set equal to zero. This indicates that CRP has tended to be associated with widening merchandising margins, rather than narrowing margins as hypothesized. However, predictions using 1998 data show that CRP was associated with narrowing margins, as hypothesized.

Thus, the effects of CRP vary by year, and its effects are unclear. In any case, the differences in margins attributable to CRP are quite small; for most elevator regions the difference is less than two cents. Further research is needed to understand these results more completely.

Conclusions

The study in this chapter determined the impact of the Conservation Reserve Program (CRP) on elevator merchandising margins in Oklahoma. It is hypothesized that this program, as well as the shorter-term Acreage Reduction Program (ARP), has had a negative effect on elevator margins by reducing harvested acres and wheat production. The impact on wheat production has not been proportional to the reduction in acreage, possibly due to slippage and wear-out effects. Since the effect differs across years, the overall effect of CRP on elevator margins is not clear. However, ARP has had a negative impact on margins.

Table 1. Description of the Variables Used in Empirical Models

Variable	Description	Unit
m_{it}	Elevator merchandising margins in year t calculated by subtracting p_{it} from p_{Rt} in ith elevator region	\$/bu
lm_{it}	Lagged value of elevator merchandising margins	\$/bu
y_{it}	Wheat production amount in year t in ith elevator region	Million bushels
y_{ait}	Anticipated wheat production amount in year t in ith elevator region	Million bushels
y_{uit}	Unanticipated wheat production amount in year t in ith elevator region	Million bushels
$CRP\%_{it}$	CRP enrollment percentage calculated by dividing CRP acres by wheat planted acres in 1980 in year t in ith elevator region	100 %
$ARP\%_t$	ARP percentage in year t in Oklahoma	100 %
p_{Rt}	Average of June daily prices paid to Oklahoma elevators by Gulf elevator in year t	\$/bu
p_{it}	Average of June daily prices paid to producers by elevators in year t in ith elevator region	\$/bu
lp_{it}	Lagged value of p_{it}	\$/bu
n_{it}	Nitrogen amount used in year t in ith elevator region	1,000 tons
ha_{it}	Wheat harvested acres in year t in ith elevator region	1,000 acres
sw_t	Steer-wheat price ratio which represents the potential revenue from feeding a steer from 550 lbs. to 750 lbs. divided by the price of the June KCBT wheat futures price in January	Cents/pound
dj_t	Difference between December and July wheat contract futures prices in KBOT on June 20^{th} in year t	\$/bu
$onst_t$	On-farm stock amount in year t in Oklahoma	Million bushels
Time	Time trend variable used to capture technological change over time	Integer

Table 2. Results of Model Selection with Heteroscedasticity and Autocorrelation Test Results for OLS Residuals

Empirical Model	Heteroscedasticity[1] Test Statistic	Autocorrelation[2] Test Statistic	Model
Harvested Acres	5.014 (0.41413)	0.3645 (0.0001)	Kmenta
Production	29.853 (0.00002)	1.1542 (0.001)	Kmenta
Linear Pricing Model	1.711 (0.63456)	1.3168 (0.0001)	Kmenta
Quadratic Pricing Model	2.634 (0.62088)	1.317 (0.0001)	Kmenta
Cubic Pricing Model	12.094 (0.03352)	1.3296 (0.0001)	Kmenta
Margins (Production)	51.402 (0.0001)	3.9975 (0.0001)	Kmenta
Margins (CRP, ARP)	25.639 (0.0012)	-0.2491 (0.4016)	Kmenta

Note: 1. Heteroscedasticity test results are obtained by B-P-G test.
2. Autocorrelation test results are obtained by DW test.
p-values are in parentheses.

Table 3. Results of Regression of Wheat Harvested Acres (1,000 acres), 1980-1998

Variable	Parameter Estimate	Standard Error	p-value
Intercept	243.26	9.338	0.000
Steer-Wheat Price Ratio	-1.3680	0.645	0.034
Lagged Price Paid($/bu.)	4.5539	0.294	0.000
Lagged CRP%	-2.1624	0.716	0.003
Lagged ARP%	-1.1295	0.271	0.000
Time	-0.69503	0.519	0.181

Notes: 1. N=285 (15 cross-sections and 19 years)
2. Buse R^2 is 0.55. Since the GLS procedure minimizes a generalized sum of squared residuals, it is more appropriate to redefine the usual R^2 statistic so that it represents the proportion of the generalized variation of the dependent variable explained by the independent variables (Kennedy, p 126).

Table 4. Results of Regression of Wheat Production (million bushels), 1980-1996

Variable	Parameter Estimate	Standard Error	p-value
Intercept	3.7119	0.1850	0.000
Lagged Price Paid ($/bu.)	0.33107	0.0135	0.000
Lagged CRP%	-0.12449	0.0301	0.000
Lagged ARP%	0.00865	0.0058	0.134
Nitrogen (1,000 tons)	0.28229	0.0113	0.000
Time	-0.09597	0.0145	0.000

Notes: 1. N=255 (15 cross-sections and 17 years)
2. Buse R^2 is 0.82.

Table 5. Results of Regression of Merchandising Margins ($/bu.) in Three Pricing Models, 1980-1996

Parameters from Equations 10-12	Linear		Quadratic		Cubic	
	Estimate	Standard Error	Estimate	Standard Error	Estimate	Standard Error
c_0 (intercept)	0.21995**	0.01308	0.21966**	0.01332	0.21741**	0.01351
c_1 (y_{ait})	0.00168*	0.00092	0.00157*	0.00093	0.00196**	0.00094
c_2 (*Time*)	-0.00216**	0.00064	-0.00212**	0.00068	-0.00211**	0.00068
c_3 (y_{uit})	-0.00676**	0.00058	-0.00696**	0.00062	-0.00761**	0.00066
c_4 (y_{uit}^2)	n.a.	n.a.	0.00008	0.00012	-0.00036	0.00023
c_5 (y_{uit}^3)	n.a.	n.a.	n.a.	n.a.	0.00006**	0.00003
Buse R^2	0.38		0.37		0.40	

Notes: 1. N=255 (15 cross-sections and 17 years)
2. ** marked coefficients are significantly different from zero at 5% significance level, and * marked coefficients are significantly different from zero at 10% significance level.

Table 6. Results of Regression of Merchandising Margins ($/bu.) Using Wheat Production as Independent Variable, 1980-1998

Variable	Parameter Estimate	Standard Error	p-value
Intercept	0.21926	0.03539	0.000
Lagged Margins ($/bu.)	0.14067	0.05675	0.013
Wheat Production (mil. bu.)	0.00544	0.00158	0.001
Time	-0.00047	0.00201	0.815
Wheat Production*Time	-0.00113	0.00035	0.001
Wheat Production*Time^2	0.00004	0.00002	0.019
On-farm Stocks on June 1 (mil. bu.)	-0.00489	0.00295	0.098
Dec.-Jul. Spread on June 1 ($/bu.)	-0.12468	0.05150	0.015

Notes: 1. N=285 (15 cross-sections and 19 years)
2. Buse R^2 is 0.11.

Table 7. Results of Regression of Merchandising Margins ($/bu.) Using CRP% and ARP% as Independent Variables, 1980-1998

Variable	Parameter Estimate	Standard Error	p-value
Intercept	0.12317	0.02372	0.000
Lagged Margins ($/bu.)	0.23911	0.04764	0.000
Lagged CRP%	-0.02770	0.01346	0.040
Lagged ARP%	-0.00556	0.00050	0.000
Time	0.00241	0.00126	0.057
Lagged CRP%*Time	0.00536	0.00189	0.005
Lagged CRP%*Time^2	-0.00022	0.00006	0.001
On-farm Stocks on June 1 (mil.bu.)	0.01814	0.00256	0.000
Dec.-Jul. Spread on June 1 (4/bu.)	-0.10604	0.03186	0.001

Notes: 1. N=285 (15 cross-sections and 19 years)
2. Buse R^2 is 0.54.

Table 8. Results of Regression of Merchandising Margins ($/bu.) Using CRP%, ARP%, and Average Yield as Independent Variables, 1980-1998

Variable	Parameter Estimate	Standard Error	p-value
Intercept	0.099882	0.02080	0.000
Lagged Margins ($/bu.)	0.24196	0.04403	0.000
Lagged CRP%	-0.030849	0.01490	0.038
Lagged ARP%	-0.0056034	0.00044	0.000
Yield	0.0014752	0.00025	0.000
Time	0.0011435	0.00111	0.303
Lagged CRP%*Time	0.0059584	0.00208	0.004
Lagged CRP%*Time^2	-0.00024459	0.00007	0.001
On-farm Stocks on June 1 (mil.bu.)	0.017042	0.00219	0.000
Dec.-Jul. Spread on June 1 (4/bu.)	-0.15721	0.02880	0.000

Notes: 1. N=285 (15 cross-sections and 19 years)
2. Buse R^2 is 0.54.

Figure 1. Trends of Wheat Production and Merchandising Margins in Blaine County of Oklahoma, 1979-1998

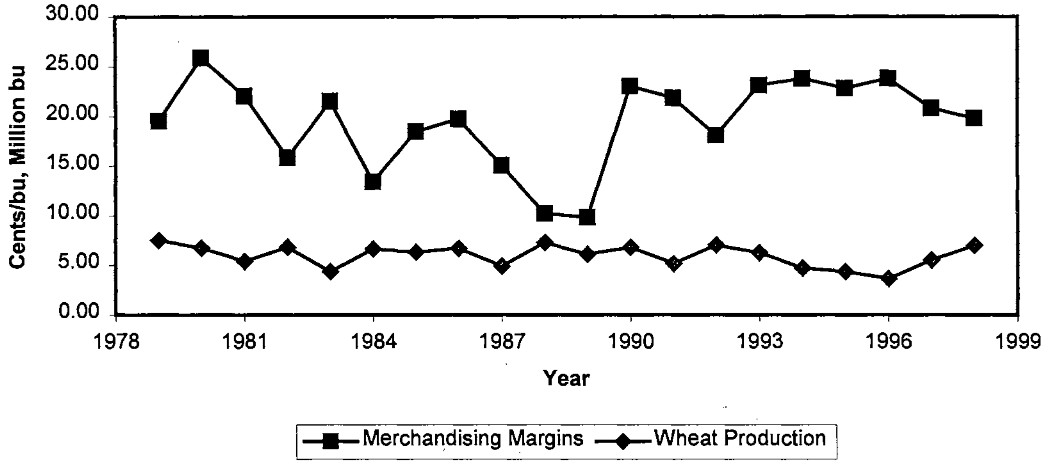


Figure 2. Trends of CRP Acres (100Acres), Planted Acres (1,000Acres), and Harvested Acres (1,000Acres) in Blaine County of Oklahoma, 1987-1998

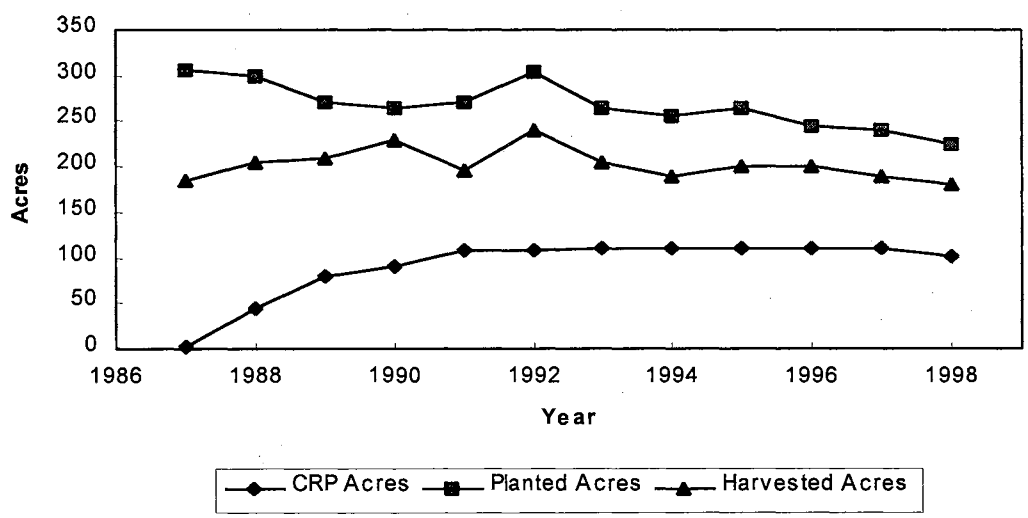


Figure 3. Wear-Out Effects of CRP on Merchandising Margins over Time

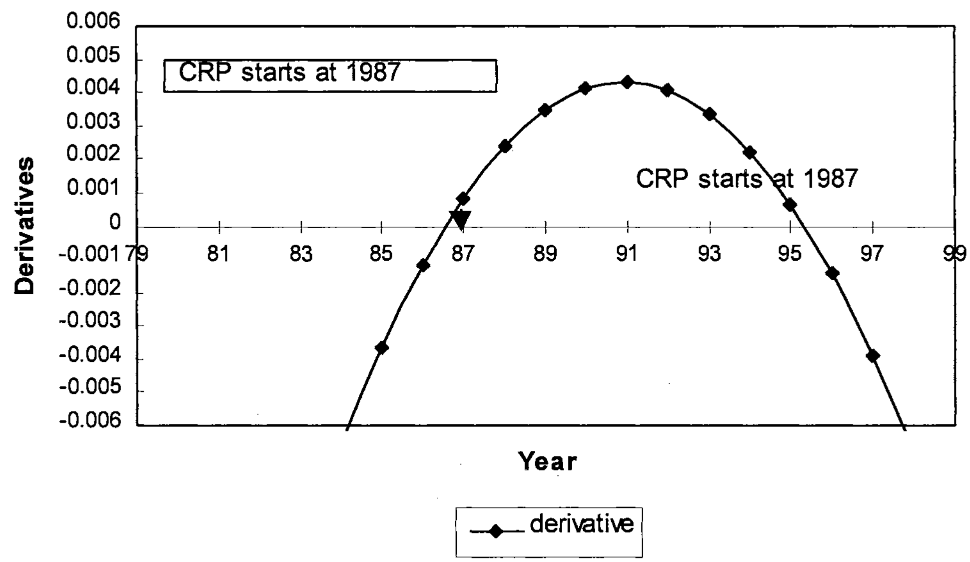
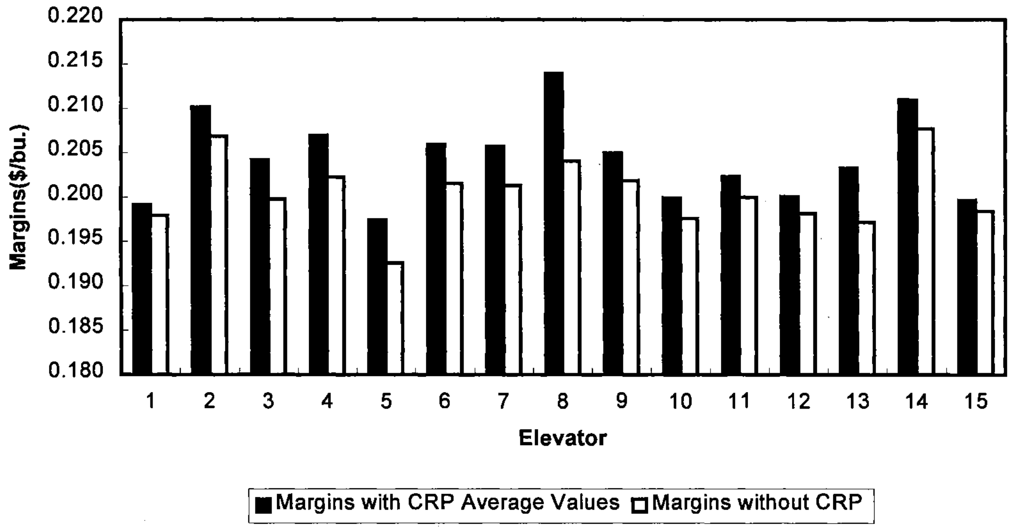
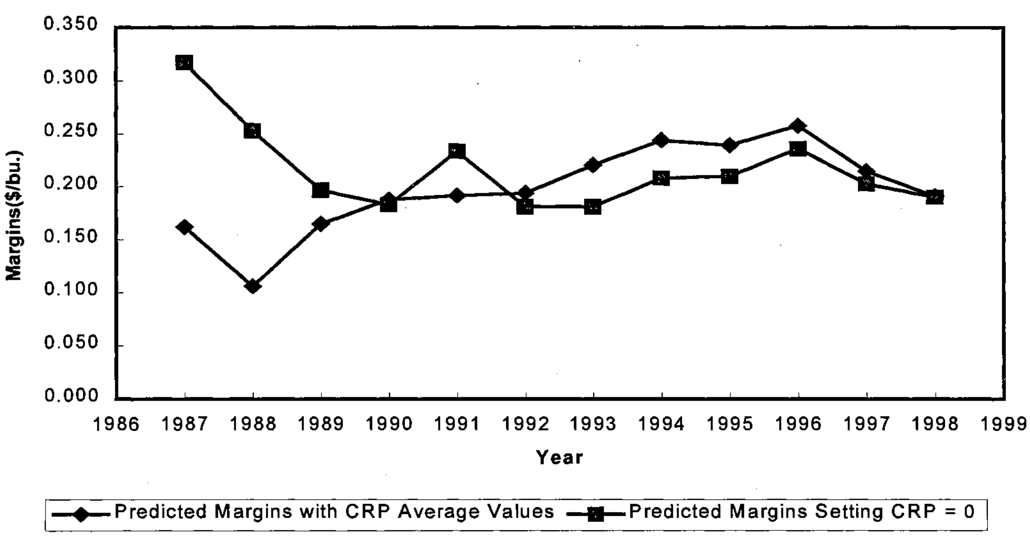


Figure 4. Predicted Merchandising Margins with CRP = Actual Average Values over 1980 – 1998 for Each Elevator Region and with CRP = 0



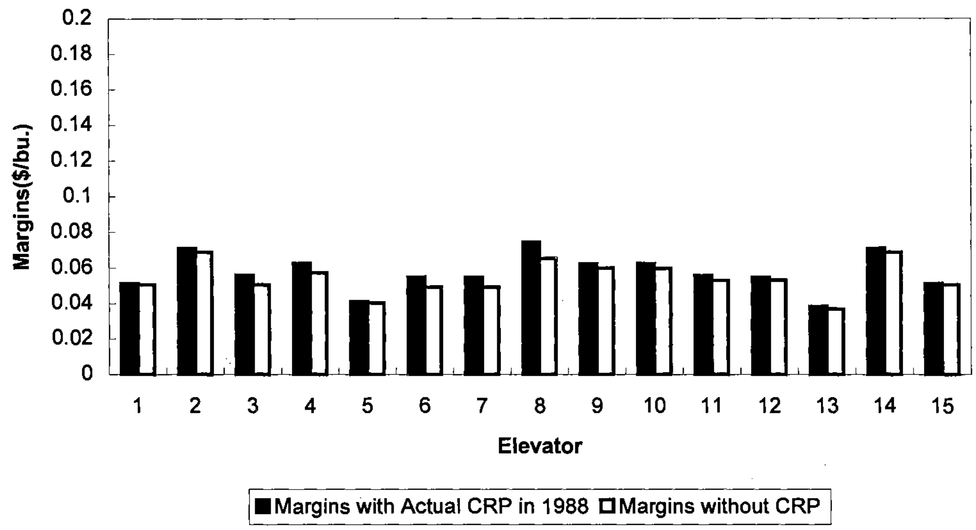
Note: 1. Merchandising Margins = f(Lagged Margins, Lagged CRP%, Lagged ARP%, Time, Lagged CRP%*Time, Lagged CRP%*Time^2, On-farm Stock on June 1, Dec.-Jul. Spread on June 1).
2. Predicted margins use CRP acres for each elevator averaged from 1980 to 1998.

Figure 5. Predicted Merchandising Margins with CRP = Actual Average Values over 15 Elevator Regions in Each Year (1987-1998) and with CRP = 0



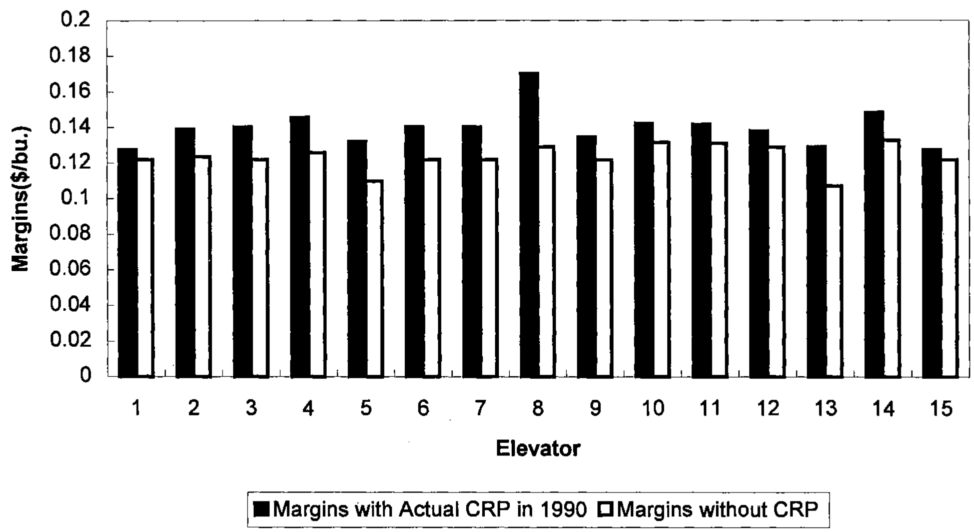
Note: 1. Merchandising Margins = f(Lagged Margins, Lagged CRP%, Lagged ARP%, Time, Lagged CRP%*Time, Lagged CRP%*Time^2, On-farm Stock on June 1, Dec.-Jul. Spread on June 1).
2. Predicted margins use CRP acres for each year averaged over 15 elevator regions.

Figure 6. Predicted Merchandising Margins with CRP = Actual Values in 1988 for Each Elevator Region and with CRP = 0



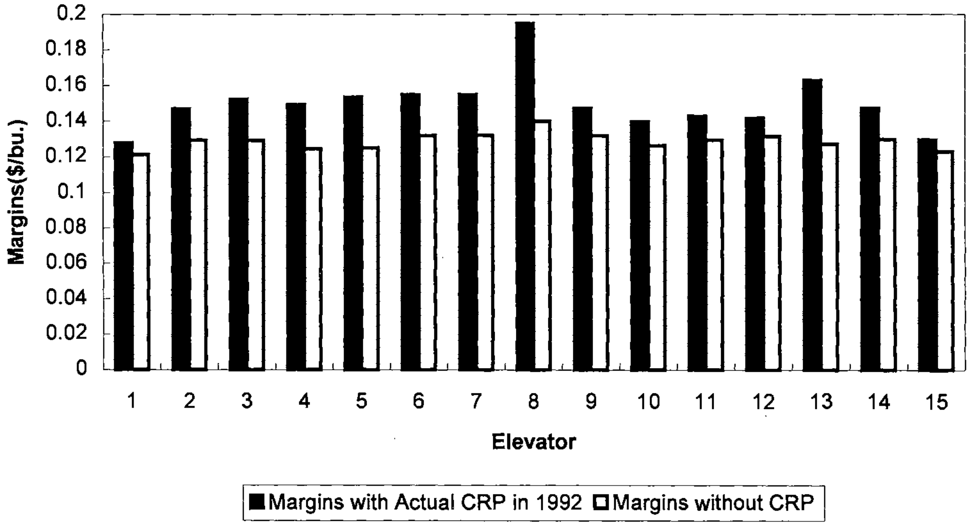
Note: 1. Merchandising Margins = f(Lagged Margins, Lagged CRP%, Lagged ARP%, Time, Lagged CRP%*Time, Lagged CRP%*Time^2, On-farm Stock on June 1, Dec.-Jul. Spread on June 1).
2. Predicted margins use CRP acres for each elevator in 1988.

Figure 7. Predicted Merchandising Margins with CRP = Actual Values in 1990 for Each Elevator Region and with CRP = 0



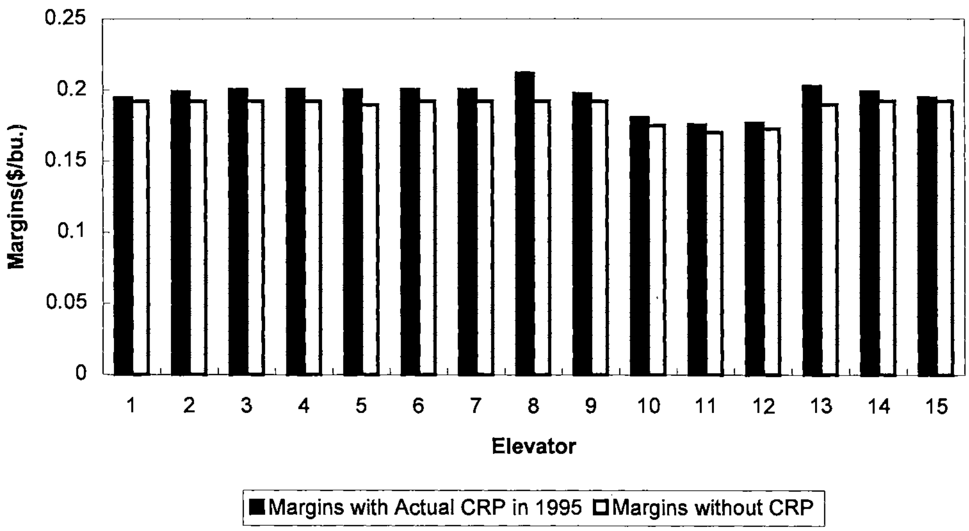
Note: 1. Merchandising Margins = f(Lagged Margins, Lagged CRP%, Lagged ARP%, Time, Lagged CRP%*Time, Lagged CRP%*Time^2, On-farm Stock on June 1, Dec.-Jul. Spread on June 1).
2. Predicted margins use CRP acres for each elevator in 1990.

Figure 8. Predicted Merchandising Margins with CRP = Actual Values in 1992 for Each Elevator Region and with CRP = 0



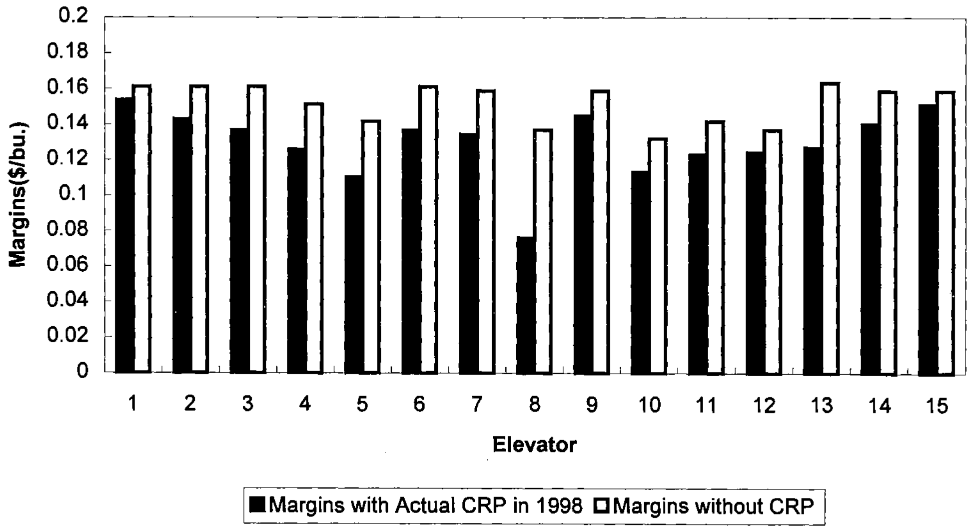
Note: 1. Merchandising Margins = f(Lagged Margins, Lagged CRP%, Lagged ARP%, Time, Lagged CRP%*Time, Lagged CRP%*Time^2, On-farm Stock on June 1, Dec.-Jul. Spread on June 1).
2. Predicted margins use CRP acres for each elevator in 1992.

Figure 9. Predicted Merchandising Margins with CRP = Actual Values in 1995 for Each Elevator Region and with CRP = 0



Note: 1. Merchandising Margins = f(Lagged Margins, Lagged CRP%, Lagged ARP%, Time, Lagged CRP%*Time, Lagged CRP%*Time^2, On-farm Stock on June 1, Dec.-Jul. Spread on June 1).
2. Predicted margins use CRP acres for each elevator in 1995.

Figure 10. Predicted Merchandising Margins with CRP = Actual Values in 1998 for Each Elevator Region and with CRP = 0



Note: 1. Merchandising Margins = f(Lagged Margins, Lagged CRP%, Lagged ARP%, Time, Lagged CRP%*Time, Lagged CRP%*Time^2, On-farm Stock on June 1, Dec.-Jul. Spread on June 1).
2. Predicted margins use CRP acres for each elevator in 1998.

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APPENDIX

Appendix A

PROCEDURES USED IN GAUSS CONSTRAINED OPTIMIZATION PROGRAM

Description of Procedures Used in GAUSS Optimization Program:

(1) Proc distcomp (valcomp): uses distance from elevator A to a producer and probability of the wheat quality to calculate producer's expected utility (prospect value).

(2) Proc elprofit (calculating elevator's profit): finds the distance from elevator A to the producer that minimizes the absolute value of the difference between U^A and U^B, so that producer is indifferent between elevator A and B. Using this distance, quantity and the profit are calculated.

(3) Constrained Optimization Routine: finds the prices for each elevator, A and B, to maximize each elevator's profit. This routine continues until the difference between successive prices for each iteration converges to very small number.

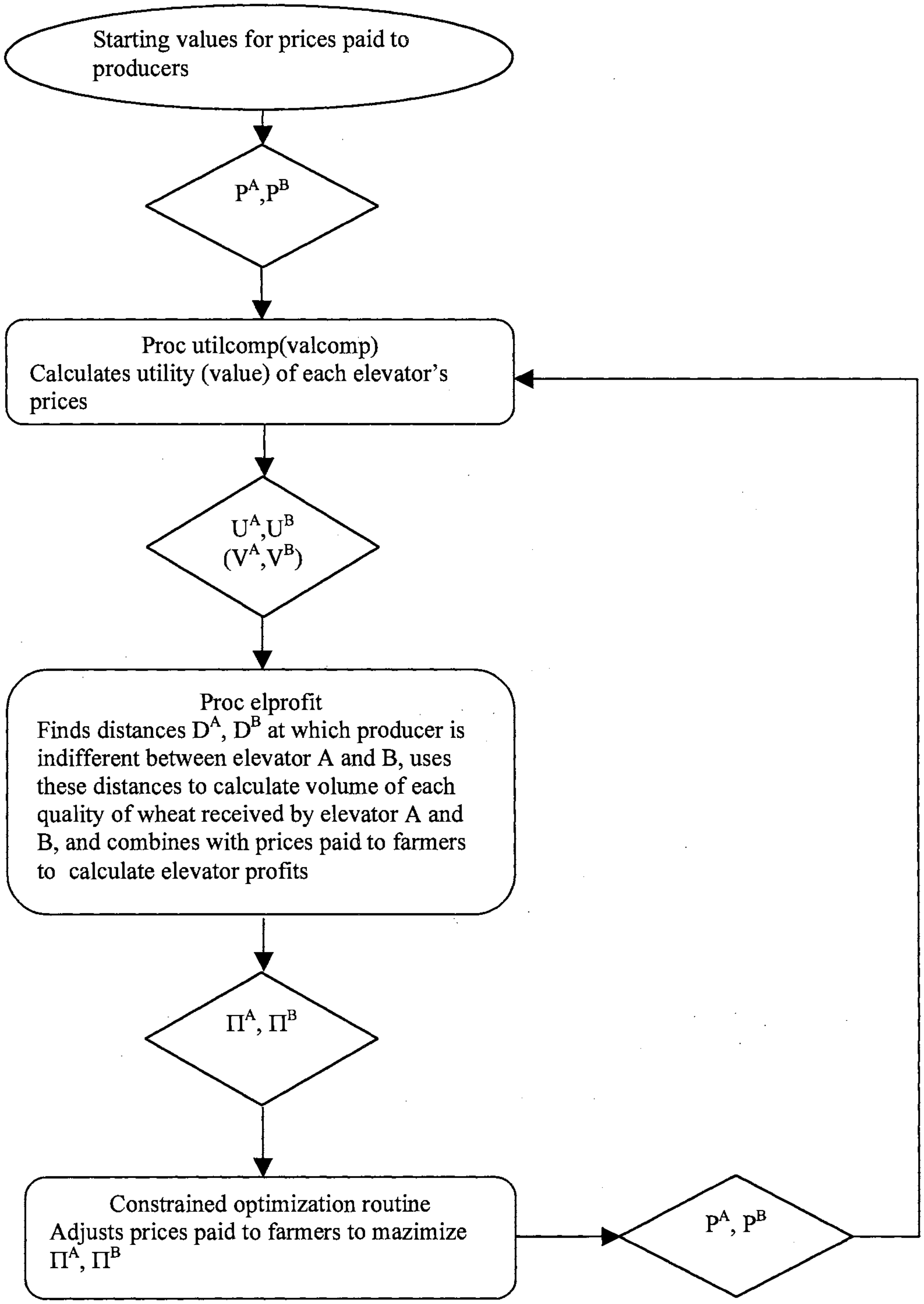

Figure 1. Flow-Chart of the Gauss Program
output variable; input variable

2

VITA

SEUNGJEE HONG

Candidate for the Degree of

Doctor of Philosophy

Thesis: ESSAYS ON THE EFFECTS OF INFORMATION, PRODUCER PREFERENCES, PROSPECT THEORY, AND NONLINEAR COSTS ON A WHEAT ELEVATOR'S PROFIT, AND THE EFFECTS OF THE CONSERVATION RESERVE PROGRAM ON WHEAT ELEVATORS' MERCHANDISING MARGINS

Major Field: Agricultural Economics

Biographical:

Personal Data: Born in Choongnam, Korea, on January 6, 1968.

Education: Graduated from Yoo-Shin High School, Suwon, Korea, in February 1986; received a Bachelor of Science degree in Agricultural Economics from Seoul National University, Seoul, Korea, in February 1990. Received a Master of Science degree at Seoul National University, Seoul, Korea, in August 1994. Completed the requirements for the degree of Doctor of Philosophy in Agricultural Economics at Oklahoma State University in May, 2001.

Experience: Graduate Research Assistant, Department of Agricultural Economics, Oklahoma State University, Stillwater, Oklahoma, September 1998 - December 2000. Employed by Korean Rural Economics Institutes as a temporary researcher, August 1994 – January 1995, Seoul, Korea.

Award: Spillman Scholarship, KSSAP Scholarship