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WHEAT CLEANING DECISIONS AT COUNTRY ELEVATORS

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ABSTRACT

This paper presents a mathematical programming model of wheat cleaning and blending decisions at a country elevator. Simulations are performed to illustrate the sensitivity of cleaning to selected variables, including the value of screenings, transportation costs, and market discounts for excess dockage. In addition, the model is used to assess the impact of including dockage in the grade standards for wheat.

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Dockage is not formally regulated in the US marketing system. In the context of current US standards, dockage is a "non-grade-determining factor." Other major wheat exporters such as Canada and Australia impose stringent grade limits on dockage. Changes have been proposed for US grade standards with a view toward reducing levels of dockage and enhancing the competitiveness of US wheat in world markets.

In evaluating such proposals, it is crucial to understand how individual firms view cleaning decisions. This report develops an analytical model of cleaning decisions from the perspective of a typical country elevator in North Dakota.

The model has features of a classic blending problem. The elevator has a number of grain bins containing wheat with different levels of dockage and other attributes. Wheat can be sold directly from each bin, or blended to meet a set of contract specifications. Cleaning is an additional activity in the model. Cleaning operations produce screenings, which are sold as animal feed. The firm realizes savings on transportation costs when wheat is cleaned prior to shipment. However, cleaning also involves a loss of salable wheat, as shrunken and broken kernels are removed with dockage.

The objective of the firm is to maximize net revenue from wheat sales and sales of screenings, net of cleaning and transport costs. The maximization is subject to a number of constraints, including maximum or minimum factor limits for wheat sold under contract. Simulations are conducted with parameters for two representative crop years, 1987 and 1990, to demonstrate the importance of interyear differences in wheat cleaning incentives. Cleaning wheat is a routine part of elevator operations in some parts of the United States, particularly in the spring wheat growing regions. Results of the simulations conducted in this study can be used to draw several important conclusions:

- *While numerous variables affect incentives to clean wheat, two of particular importance are the value of screenings and the cost of freight. Increases in these variables induce additional cleaning by the country elevator. Incentives to clean are also highly dependent on market conditions which change through time.*

- *Though not pervasive in current trading practices, an alternative to imposing regulations to induce cleaning is for buyers and sellers to negotiate discounts for dockage in excess of particular levels. In 1987 a discount of 1/2 cent per bushel would have induced additional cleaning to 0.5 percent dockage.*

- *Introduction of grade factor limits for dockage with a breakpoint at 0.5% between grades 3 and 4 would have had minimal impact on cleaning activity in 1990. However, this would have resulted in increased cleaning in 1987, at an additional cost of 0.7 cents per bushel.*

Our results suggest that proposed changes in grade standards would have little impact on cleaning decisions by country elevators. Other incentives already induce cleaning in the spring wheat region. However, our model is developed from the perspective of an elevator with adequate cleaning capacity in place. The impact of a change in standards would fall heavily on elevators that lack such capacity.

WHEAT CLEANING DECISIONS AT COUNTRY ELEVATORS

D. Demcey Johnson, Daniel J. Scherping, and William W. Wilson[1]

I. Introduction

U.S. grain quality and the interaction of official standards with commercial needs are subjects of continuing interest to policy makers. Recently, attention has focused on the implications of dockage and other quality characteristics for U.S. export competitiveness. A comprehensive analysis by the Office of Technology Assessment (OTA) provided motivation for several features of the 1990 Farm Bill pertaining to grain quality. However, issues related to grain cleanliness have been debated for at least a decade, and allegations have frequently been made that high levels of dockage (non-millable material) place U.S. wheat at a competitive disadvantage in world markets. While other exporting countries (e.g., Canada and Australia) clean wheat intensively before export, U.S. dockage levels are not subject to formal regulation. The existing U.S. standards treat dockage (like protein) as a non-grade-determining factor. Contract specifications and commercial incentives determine dockage levels in U.S. wheat exports and throughout the marketing system.

There have been numerous proposals to "regulate" dockage through changes in grade standards.[2] When evaluating such proposals, it is crucial to understand how economic factors and commercial trade practices influence firm-level cleaning decisions. The objective of this study, which is one of four prepared under a USDA cooperative agreement,[3] is to develop an analytical model of cleaning decisions.

A decision model for a representative country elevator is presented. Simulations are performed to illustrate impacts of important variables on the economics of cleaning and to assess implications of alternative constraints. The model is normative: it identifies an "optimal" set of actions by the elevator given an objective of profit maximization. For this reason, the model can be used to predict how individual firms would respond to new regulations or other changes in the economics of cleaning.

Previous studies (e.g., Kiser) have developed budget analyses to evaluate the costs and benefits of cleaning wheat. Our model differs in several respects. The intensity of cleaning operations (i.e., quantity of grain cleaned and amount of dockage removed),

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[1]Johnson is Assistant Professor, Scherping is Research Assistant, and Wilson is Professor in the Department of Agricultural Economics, North Dakota State University, Fargo.

[2]Mercier, et al. examine the implications of combining dockage with foreign material in the grading standards for wheat. Recently, the Federal Grain Inspection Service has considered introducing a separate grade limit for dockage.

[3]Scherping et al. provide a comprehensive review of commercial practices and costs of cleaning in the spring wheat area. Johnson and Wilson examine the implications of dockage for importers and U.S. export firms. Wilson, Scherping, Johnson and Cobia provide an overview of policy issues relating to dockage.

which other studies have treated as exogenous, is derived as part of the model solution. Further, dockage levels (and other quality attributes) are assumed to vary across bins, and blending activities are allowed to substitute for cleaning. These features make the model more realistic and improve the quality of simulations.

The report is organized as follows: In the next section, the decision model is formally described. Data for the analysis are summarized in the third section. The fourth section presents results of sensitivity analyses along with simulations intended to quantify the costs of cleaning under different assumptions. The paper concludes with a summary of our results.

II. Model Specifications

The decision model has much in common with a classic blending problem (see Schruben 1968 and Ladd and Martin 1976 for examples in grain). An elevator has a number of grain bins, each containing some quantity of wheat with specific quality attributes. Quantities and qualities vary across bins and are taken as given by the decision maker. Wheat can be sold directly from each bin or blended to meet a set of contract specifications (e.g., protein, test weight, dockage, damage, or defects). Different prices apply to wheat that is sold separately and to wheat that is blended to satisfy contract specifications. The objective is to maximize sales revenue net of various costs.

Introduction of wheat cleaning adds complexity to the blending problem. Unlike other wheat quality attributes which can be altered only through blending activities, the level of dockage in each bin can be controlled independently through cleaning operations. The elevator sells wheat on a dockage-deductible basis, that is, the sales price applies to weight net of dockage. Since freight charges are based on gross weight inclusive of dockage, the elevator realizes savings on freight costs by cleaning before shipment.[4] In addition, material removed through cleaning operations (screenings) can be sold as animal feed. The sum of freight savings and screening values less the cost of cleaning represents an implicit "cleaning margin," which may be positive or negative. Positive implicit cleaning margins provide incentives to remove dockage from wheat before shipment.

The elevator is assumed to have standard disk-cylinder cleaning equipment. Costs of operating this equipment depend on the quantity cleaned and on the intensity of cleaning operations. Cleaning to lower dockage levels involves a reduction of operating efficiency, i.e., longer running time for the machinery. Cleaning operations also involve a loss of salable wheat, as shrunken and broken kernels are removed along with dockage. This "wheat loss" can represent a substantial part of cleaning costs, depending on the level of shrunken and broken kernels in the grain being cleaned and the relative values of wheat and wheat screenings.[5]

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[4]Note that freight costs are incurred by the country elevator rather than by the buyer. That is standard practice in the spring wheat region.

[5]As a component of cleaning costs, wheat loss would be reflected in the "implicit cleaning margins" described above.

The analysis proceeds from a number of simplifying assumptions. Blending is assumed to be costless. The model takes no account of incentives to clean based on "improved storability" or limited storage capacity. Inflows of grain to the elevator (and decisions about cleaning prior to binning) are not incorporated in the model. Rather, we adopt the perspective of a merchandiser with known stocks, facing known prices. Because the model is static, it does not match the complexity of an actual merchandising environment. However, it does highlight the influence of specific factors (e.g., price relationships, grain quality, and contract terms) on firm-level cleaning decisions.

The remainder of this section is somewhat technical. Readers who have no interest in formal specifications can skip to the third section without much loss of continuity. The notation is identical to that of the computer program used in model simulations; variable indexes are enclosed in parentheses, rather than converted into subscripts. Copies of the program are available from the authors upon request.

Ten storage bins are indexed by i (i = 1, 2,..., 10), containing wheat with different levels of the following attributes: dockage (DK), protein (PRO), test weight (TW), shrunken and broken kernels (SB), foreign material (FM), damage (DAM), and defects (DEF). The elevator can satisfy two (or potentially more) sets of contract specifications through blending; alternatively, the elevator can sell wheat directly from bins without blending. Formally, let K represent a set of marketing choices:

$$k \in K = \{ NB, B1, B2 \}$$

where NB indicates *do not blend*; B1 indicates *blend number 1*; and B2 indicates *blend number 2*. For later convenience, define L as a subset of K, consisting of the two blends:

$$l \in L = \{ B1, B2 \} \subset K$$

Let J represent a set of (binary) cleaning choices:

$$j \in J = \{ C, NC \}$$

where C indicates *clean*, and NC indicates *do not clean*.

Let X(i,j,k) denote the quantity (60-lb. bushels) from bin i devoted to cleaning alternative j and marketing alternative k. Thus, X(i,'C','NB') represents the quantity of wheat from bin i that is cleaned but sold directly without blending; X(i,'NC','B1') is the quantity from bin i that is not cleaned, but blended and sold under the first set of contract specifications. All of the grain is allocated (sold) under some combination of cleaning and marketing alternatives:

$$\sum_{j}\sum_{k} X(i,j,k) \leq QTY(i) \quad for\ all\ i$$

where QTY(i) is the total quantity of wheat (bushels) available in bin i.

Cleaning costs depend on the operating efficiency of the disk-cylinder equipment. The rated capacity of this equipment, denoted RCAP, represents maximum throughput (bushels per hour) under ideal conditions. In practice, operating efficiency depends on the intensity of cleaning operations, i.e., the initial level of dockage and the level of dockage after cleaning. A linear relationship is specified:

$$PRC(i,k) \leq a_0 + a_1 \cdot DK(i) + a_2 \cdot EDK(i,k)$$

where PRC(i,k) denotes proportion of rated capacity; DK(i) is the initial level of dockage (percentage) in bin i; and EDK(i,k) is the desired ending level of dockage after cleaning operations. Operating efficiency is inversely related to the ending level of dockage (the coefficient a_2 is negative). An upper bound is also applied:

$$PRC(i,k) \leq 1$$

so that actual throughput rates are not allowed to exceed rated capacity for the equipment.

The initial dockage DK(i) is given, but the decision maker chooses EDK(i,k) for each bin and marketing alternative. For obvious reasons, the ending dockage level is constrained to be less than the beginning dockage level:

$$EDK(i,k) \leq DK(i)$$

The time required to complete a cleaning operation, MT(i,k) depends on the quantity of wheat cleaned, the cleaner capacity, and operating efficiency:

$$MT(i,k) = \frac{X(i,'C',k)}{[RCAP \cdot PRC(i,k)]}$$

An hourly cost CPH is imputed to cleaning operations. This represents the sum of variable costs (labor, electricity, replacement parts) for the disk-cylinder equipment. Additional handling costs (such as elevation costs) may be associated with cleaning operations. Let HC denote this extra handling cost, expressed in dollars per bushel. Cleaning costs are given by:

$$CC(i,k) = CPH \cdot MT(i,k) + HC \cdot X(i,'C',k)$$

$$TCC = \sum_i \sum_k CC(i,k)$$

where CC(i,k) denotes the cost of cleaning grain from a particular bin and for a particular marketing alternative and TCC denotes the total cost of cleaning.

In addition to the costs of operating the equipment, the model allows for a loss of salable wheat. This wheat loss consists of shrunken and broken kernels that are removed along with dockage during cleaning operations. Specifically, removal of shrunken and broken kernels is assumed to be proportional to removal of dockage:

$$ESB(i,k) = SB(i) \cdot [EDK(i,k)/DK(i)]$$

where ESB(i,k) denotes ending shrunken and broken percentage after cleaning operations and SB(i) denotes the initial percentage before cleaning. Screenings are given by:

$$S(i,k) = \frac{DK(i) - EDK(i,k) + SB(i) - ESB(i,k)}{100} \cdot X(i,'C',k)$$

$$TS = \sum_i \sum_k S(i,k) \cdot \frac{60}{2000}$$

where S(i,k) represents screenings (60 pounds) from a particular cleaning operation and TS represents total screenings (tons). The ratio 60/2000 is used to convert units of measurement. Screenings are sold at a price PS. The value of wheat loss depends on the quantity of shrunken and broken kernels removed and on the value of screenings relative to wheat.

To facilitate other model specifications, several quantities are defined. Let Y(i,j,k) denote bushels after (optional) cleaning operations:

$$Y(i,j,k) = \begin{cases} X(i,'C',k) - S(i,k) & \text{if wheat is cleaned} \\ X(i,'NC',k) & \text{otherwise} \end{cases}$$

These quantities represent gross bushels (inclusive of dockage) sold directly, or blended under a set of contract specifications. For the two blends, total gross bushels (TGW) are given by:

$$TGW(l) = \sum_i \sum_j Y(i,j,l) \qquad \text{for } l = B1,\ B2$$

Bushels net of dockage, denoted N(i,j,k), are defined as follows:

$$N(i,j,k) = \begin{cases} Y(i,'C',k) \cdot \left[\dfrac{100 - EDK(i,k)}{100}\right] & \text{if wheat is cleaned} \\ Y(i,'NC',k) \cdot \left[\dfrac{100 - DK(i)}{100}\right] & \text{otherwise} \end{cases}$$

Total net bushels (TNW) for the two blends are given by:

$$TNW(l) = \sum_i \sum_j N(i,j,l) \qquad \text{for } l = B1,\ B2$$

Let M(i,j,k) denote bushels net of dockage and shrunken and broken kernels:

$$M(i,j,k) = \begin{cases} N(i,'C',k) \cdot \left[\dfrac{100 - ESB(i,k)}{100}\right] & \text{if wheat is cleaned} \\ N(i,'NC',k) \cdot \left[\dfrac{100 - SB(i)}{100}\right] & \text{otherwise} \end{cases}$$

For the two blends, the associated totals are defined:

$$TMW(l) = \sum_i \sum_j M(i,j,l) \qquad for\ l = B1,\ B2$$

These quantities are used in specification of constraints--particularly those identified with contract limits for foreign material and damage.

Opportunities for blending are limited by the quantity and quality of wheat in different bins and by contract specifications. For each of the two blends, contract limits are specified for protein, test weight, dockage, shrunken and broken kernels, foreign material, damage, and total defects. These have the following form (for l = B1, B2):

$$Protein(l)$$
$$= \sum_i \sum_j \left[\frac{N(i,j,l)}{TNW(l)}\right] \cdot PRO(i) \geq constant$$

$$Test\ Weight(l)$$
$$= \sum_i \sum_j \left[\frac{N(i,j,l)}{TNW(l)}\right] \cdot TW(i) \geq constant$$

$$Dockage(l)$$
$$= \sum_i \left[\frac{Y(i,'C',l) \cdot EDK(i,l) + Y(i,'NC',l) \cdot DK(i)}{TGW(l)}\right] \leq constant$$

$$Shrunken\ and\ Broken(l)$$
$$= \sum_i \left[\frac{N(i,'C',l) \cdot ESB(i,l) + N(i,'NC',l) \cdot SB(i)}{TNW(l)}\right] \leq constant$$

$$Foreign\ Material(l)$$
$$= \sum_i \sum_j \left[\frac{M(i,j,l)}{TMW(l)}\right] \cdot FM(i) \leq constant$$

$$Damage(l)$$
$$= \sum_i \sum_j \left[\frac{M(i,j,l)}{TMW(l)}\right] \cdot DAM(i) \leq constant$$

$$Total\ Defects(l)$$
$$= Foreign\ Material(l) + Damage(l)$$
$$+ Shrunken\ and\ Broken(l) \leq constant$$

Definitions of these factors are consistent with Federal Grain Inspection Service (FGIS) testing procedures. The percentage of shrunken and broken kernels is based on a dockage-free sample, while foreign material and damage are calculated after removal of dockage and shrunken and broken kernels. Minimum contract limits apply to protein and test weight. Maximum limits apply to dockage, shrunken and broken kernels, damage and defects.

Let T denote the freight cost ($ per bushel) of the elevator for all wheat sales. This is applied to the gross weight of shipments, inclusive of dockage. Total transportation costs are given by:

$$TRAN = T \cdot \left[\sum_i \sum_j Y(i,j,'NB') \quad + \quad \sum_l TGW(l) \right]$$

Let P(i) denote the price at which the elevator can sell wheat (on a dockage-deductible basis) directly from bin i, and let PC(l) denote the price associated with blend contract l. The objective function can now be specified. The elevator seeks to maximize its revenue from wheat sales and sales of screenings, net of cleaning and transportation costs:

$$\begin{aligned} Net\ Revenue = & \sum_i \sum_j P(i) \cdot N(i,j,'NB') \quad + \quad \sum_l PC(l) \cdot TNW(l) \\ & + PS \cdot TS \quad - \quad TCC \quad - \quad TRAN \end{aligned}$$

Maximization of the objective function is subject to the constraints--including identities, and constraints concerning resource availability or contract limits--that are outlined above.

Because of various nonlinear constraints, the "feasible region" for the maximization problem is not convex. This means that, contrary to standard LP models, there is no mathematical assurance that a "local" optimum is simultaneously "global." One way to deal with this difficulty is to solve the model with different sets of initial values for selected variables. If the nonlinear solver generates the same solution irrespective of the chosen initial values, there is reason to believe that a global solution has, in fact, been identified. (See Brooke, et al. p. 157). We have adopted this approach in developing and checking the model. Based on some experimentation, we have confidence in the quality of results when the initial values for selected variables, i.e., ED(i,k) and X(i,j,k), are not at their upper or lower bounds.

III. Data for Model Simulations

The model is intended to represent a typical country elevator in North Dakota. Cleaning technology and costs were derived from an elevator survey and engineering cost study (Scherping et al). Other features of the model are based on regional crop-quality data, average price relationships, and discussions with industry representatives.

Factors affecting cleaning and blending decisions are highly variable. Since prices and quality attributes of wheat available for blending vary over time, framing a "typical" cleaning/blending problem is inherently difficult. Our approach is to perform simulations with two different sets of parameters, corresponding to two different crop years. The two years, 1987 and 1990, provide an interesting contrast. Average dockage levels were high in 1987, and the value of screenings was low, whereas the opposite was true in 1990. Simulation results for 1987 and 1990 illustrate the sensitivity of model results to these key parameters.

Grain quality data were taken from results of an annual wheat quality survey in which the NDSU Department of Cereal Science and Food technology tests wheat samples from throughout the Hard Red Spring (HRS) growing region.[6] Each sample is evaluated in terms of protein, dockage, and grade factors. Collectively, the samples describe a distribution of HRS quality attributes for a particular crop year.

We assign quality attributes to bins of our hypothetical elevator as follows: Individual samples from the regional survey are interpreted as truckloads of grain received. Truckloads are allocated to ten bins, depending on the level of protein and dockage. The bins are "filled" according to a scheme that is consistent with observed practices of country elevators, as shown in Table 1.

Table 1:
Assumed Binning Decisions

	Dockage	
Protein	DK ≤ 1.0	DK > 1.0
PRO < 13	BIN 1	BIN 2
13 < PRO ≤ 14	BIN 3	BIN 4
14 < PRO ≤ 15	BIN 5	BIN 6
15 < PRO ≤ 16	BIN 7	BIN 8
PRO > 16	BIN 9	BIN 10

Thus, truckloads with protein and dockage within specified ranges are pooled together. Within each pool (i.e., each bin), averages are computed for all quality attributes.[7] The resulting matrix of attributes, displayed in Tables 2 and 3, provides the basis for our blending problem.

In addition to quality attributes, Tables 2 and 3 list quantities and prices for each bin. The quantities reflect observed distributions (i.e., proportion of grain allocated to

[6]Survey results are summarized in Shelton et al. and D'Appolonia et al. Raw sample data were furnished by the Department of Cereal Science and Food Technology; these were used to develop a representative distribution of wheat quality attributes for our hypothetical elevator.

[7]This mimics the "blending" of incoming grain through binning decisions. However, these decisions are not formally part of our analytical model.

Table 2:
Quality Attributes and Other Bin Parameters, 1987

	BIN1	BIN2	BIN3	BIN4	BIN5	BIN6	BIN7	BIN8	BIN9	BIN10
PRO	12.54	12.43	13.58	13.58	14.50	14.42	15.45	15.40	16.57	16.47
DK	0.64	1.95	0.61	2.15	0.56	2.58	0.59	2.69	0.55	3.33
TW	60.53	59.01	60.61	59.42	59.93	58.12	59.57	58.65	59.81	57.81
SB	1.04	1.30	0.83	1.14	0.93	1.14	0.78	0.97	0.74	1.20
FM	0.08	0.41	0.17	0.18	0.07	0.29	0.06	0.23	0.05	0.54
DAM	0.32	1.05	0.50	0.41	0.37	0.70	0.46	0.59	0.60	0.63
DEF	1.45	2.42	1.36	1.75	1.35	2.15	1.30	1.79	1.39	2.33
QTY	4	6	8	11	14	22	12	14	4	5
PRICE	2.93½	2.92	3.04½	3.03	3.39	3.33	3.89	3.85½	4.27½	4.24

Table 3:
Quality Attributes and Other Bin Parameters, 1990

	BIN1	BIN2	BIN3	BIN4	BIN5	BIN6	BIN7	BIN8	BIN9	BIN10
PRO	12.44	12.48	13.44	13.51	14.42	14.44	15.40	15.28	16.54	16.95
DK	0.36	1.65	0.36	2.08	0.38	1.93	0.37	2.09	0.52	1.61
TW	61.67	59.70	61.23	58.76	61.17	58.66	60.79	58.86	59.12	57.74
SB	1.00	1.30	1.02	1.41	0.89	1.50	1.10	1.42	1.41	1.54
FM	0.02	0.09	0.04	0.07	0.03	0.11	0.03	0.17	0.05	0.04
DAM	0.12	1.41	0.30	1.52	0.23	1.14	0.25	0.69	0.09	0.15
DEF	1.14	2.81	1.36	3.00	1.16	2.75	1.39	2.30	1.56	1.73
QTY	9	5	20	9	18	12	11	7	5	4
PRICE	2.77	2.75½	2.82½	2.80	3.02	3.00	3.28	3.24½	3.32½	3.31½

individual bins) for individual crop years. Quantities are in thousand bushels; for simplicity, they are normalized to sum to 100 thousand. Prices ($/bu) are based on actual market quotations and include applicable premiums for protein and test weight.[8] These are the prices that would apply to wheat sold directly from individual bins; consequently, they also represent (gross) opportunity costs for bushels that are blended under terms of a given contract. Price spreads between high and low protein wheat were substantially larger in 1987 than in 1990.

The cleaning cost specification has two principal components: the efficiency of the disk-cylinder equipment and the cost per hour of operation. A leading manufacturer provided the following estimates of throughput rates for different levels of beginning and ending dockage:

Table 4:
Operating Efficiency of Disk-Cylinder Cleaner

Proportion of Rated Capacity (PRC) as Function of:

Ending Dockage (EDK)	Beginning Dockage (DK) 5%	3%	1%
1.0%	.6	.8	--
0.7%	.5	.7	1.0
0.4%	.4	.6	.8
0.1%	.3	.5	.6

Regressing proportion of rated capacity on beginning and ending dockage, we obtained the following equation (t-statistics in parentheses):

$$PRC = .7449 - .1019\ DK + .3882\ EDK \qquad \text{Adj. } R^2 = .95$$
$$(21.03) \quad (11.54) \quad (8.88)$$

These relationships are shown graphically in Figure 1. Because ending dockage is constrained to be no greater than beginning dockage, the triangular section at the lower left of Figure 1 has no practical interpretation.

[8]Based on Minneapolis spot prices, with relevant premiums and discounts, as quoted in The Forum (September 17, 1987, and September 14, 1990).

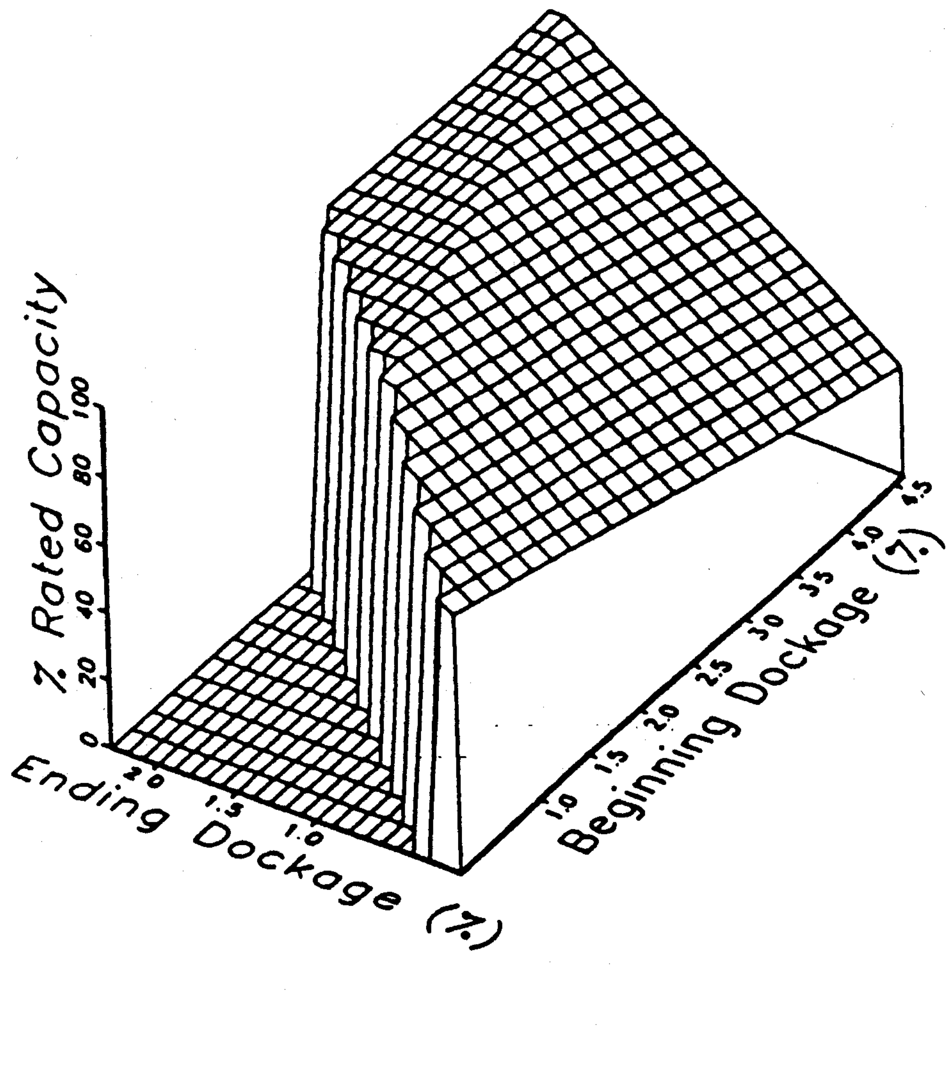

Figure 1:
Disk Cylinder Operating Efficiency

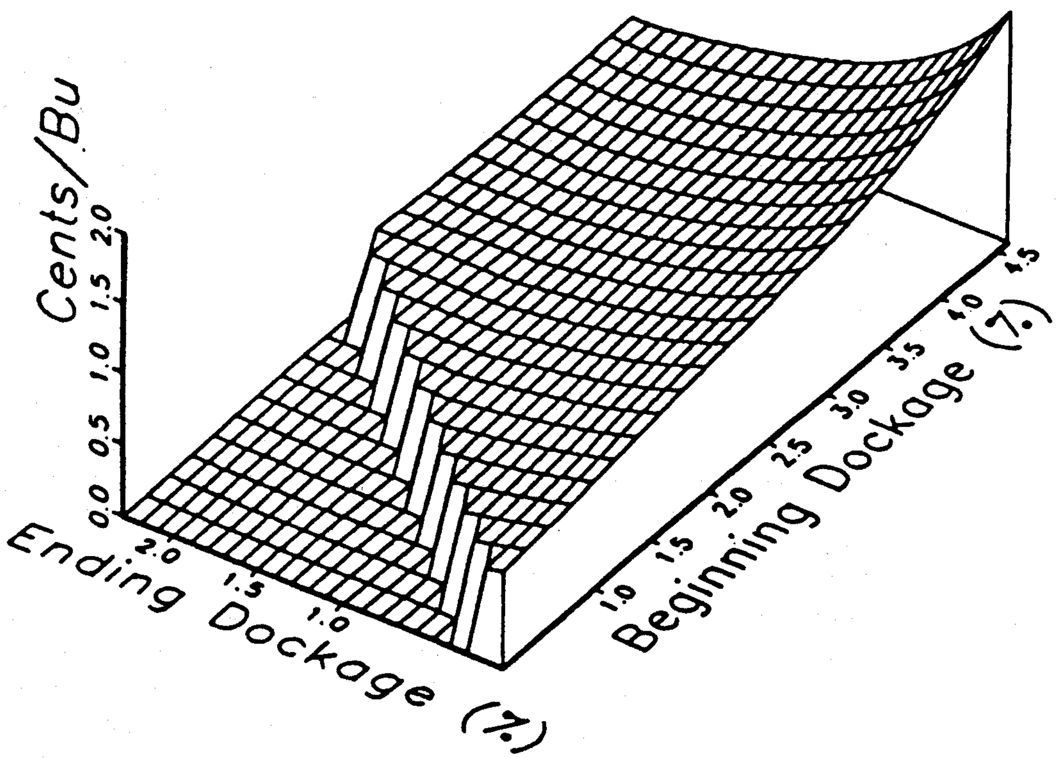

Figure 2:
Disk-Cylinder Operating Costs

Operating costs are estimated at $5.05 per hour.[9] This includes costs of electricity, labor, and replacement parts for the disk-cylinder cleaner. It does not include depreciation or opportunity costs of capital. Extra handling costs (HC) are assumed to be zero.[10] Figure 2 displays operating costs on a per-bushel basis. Per-bushel costs depend on operating efficiency and, hence, on beginning and ending dockage levels.

For base-case simulations, the value of screenings is $10 per ton in 1987 and $30 per ton in 1990, average North Dakota values in those years. The cost of freight in the base case is $.85 per bushel. This is a weighted average of freight costs from North Dakota to principal markets.

IV. Simulation Results

Results of several simulations are reported in this section. First, the model is solved with different values of two key parameters--the value of screenings and the cost of transportation--to illustrate the sensitivity of model solutions. Second, simulations are performed to evaluate the "minimum discounts" necessary to induce cleaning, given a set of contract specifications. Third, we examine the impact of including dockage as a grade-determining factor.

Sensitivity Analysis

The "supply function" for screenings provides one way to illustrate the economics of cleaning. As stated earlier, incentives to clean are directly influenced by the value of screenings and by the cost of transportation. However, the supply of screenings may shift from year to year, depending on overall levels of dockage in wheat received by the elevator and other parameters.

Figures 3 and 4 show the elevator's supply of screenings for two years, using crop quality data from 1987 and 1990. The figures are based on sets of simulations in which the value of screenings and the cost of transportation were varied parametrically. For simplicity, other parameters were adjusted to remove any influence of contract limits on cleaning. Quantities (tons of screenings) are measured along the vertical axis in each figure.

The price of screenings (Figure 3) shows a pronounced impact on supply for both years. For screenings prices below $15 to $20 per ton, the implicit margin is apparently negative: cleaning does not occur and no screenings are produced. Larger volumes of screenings are associated with each price in 1987, due to higher average dockage levels.

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[9]See Scherping et al. for details. The disk-cylinder equipment corresponds to "Cleaner B" in that report.

[10]If handling costs were introduced, smaller volumes of grain would be cleaned. The impact would be lessened by changes in the intensity of cleaning (higher proportion of dockage removed).

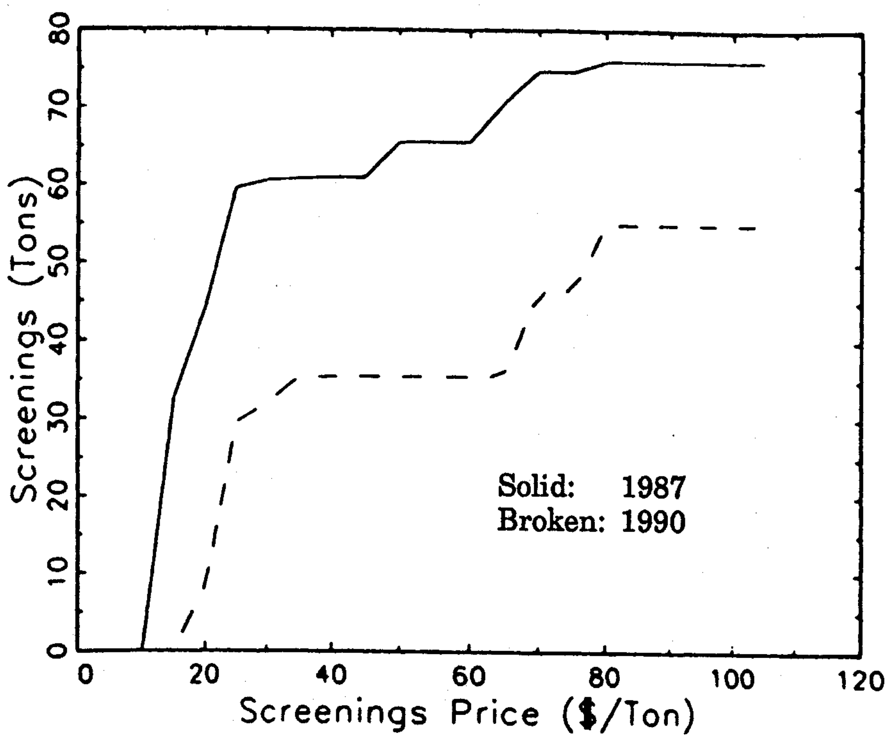

Figure 3:
Supply of Screenings as Function of Price of Screenings

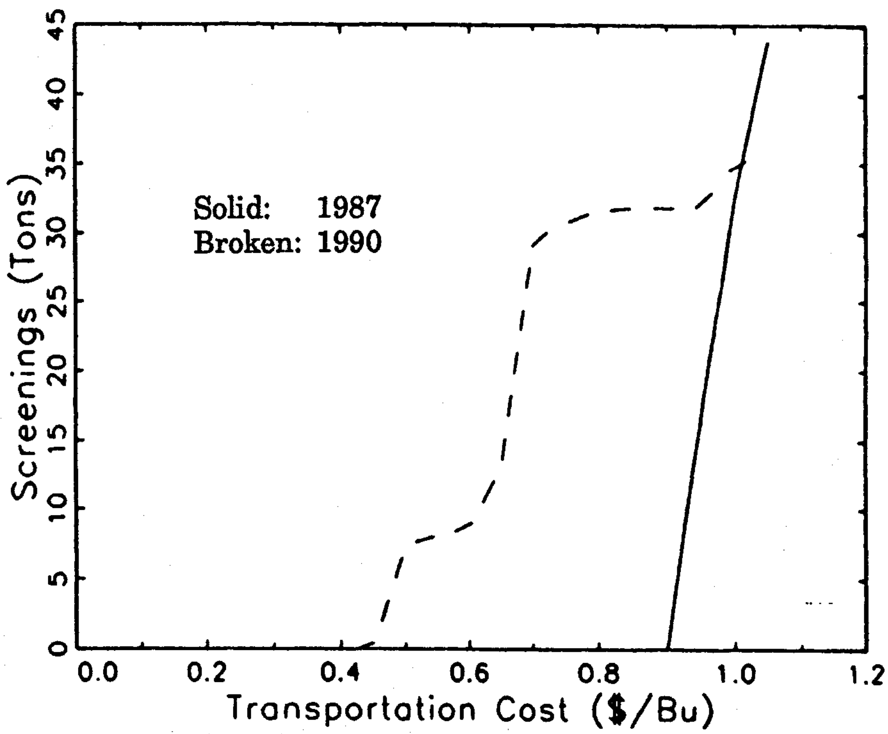

Figure 4:
Supply of Screenings as Function of Cost of Transportation

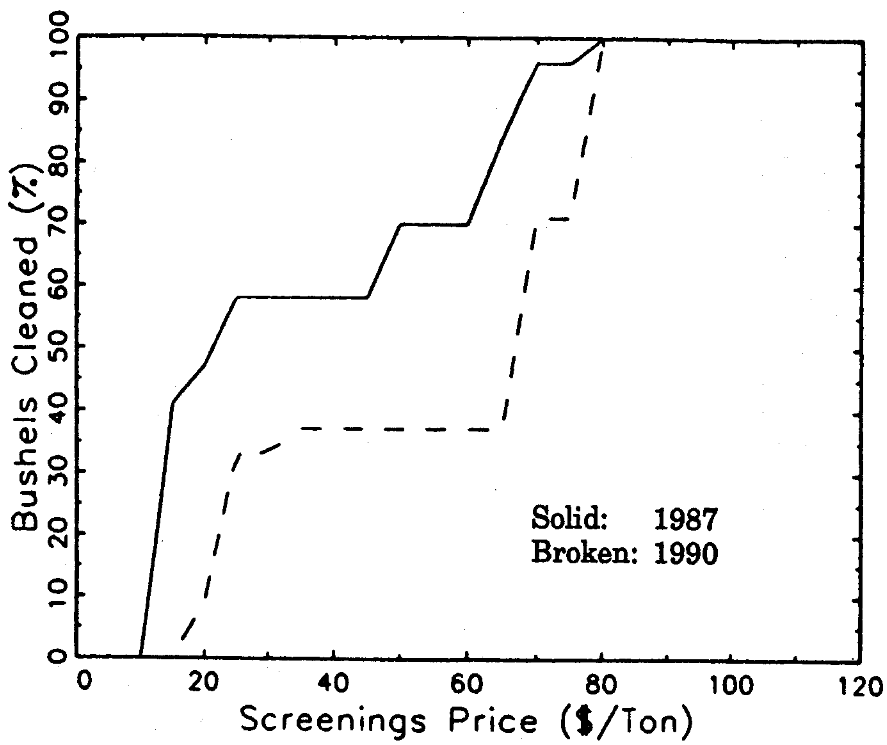

Figure 5:
Bushels Cleaned as Function of Price of Screenings

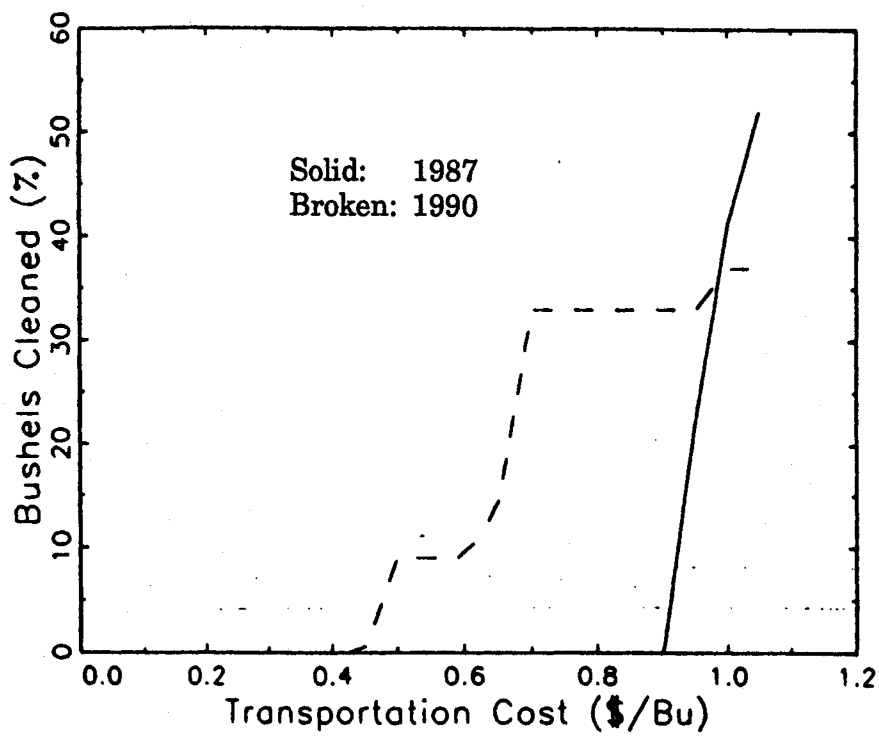

Figure 6:
Bushels Cleaned as Function of Cost of Transportation

Market and quality conditions of 1990 are such that a higher price for screenings is necessary to induce cleaning. That can be attributed to lower beginning dockage levels[11] and higher levels of shrunken and broken kernels (which affect wheat loss).

Transportation costs also affect the supply of screenings (Figure 4). Higher costs induce more cleaning (and therefore screenings) because of greater implied savings on freight. Paradoxically, the impact is more pronounced under conditions of 1990, when dockage levels were low. The price of screenings was also higher that year--$30 per ton, versus $10 per ton in 1987. Given the low screening values of 1987, transportation costs of $.90 per bushel (higher than assumed in the base case) would be necessary to induce cleaning at our hypothetical elevator. This highlights the *combined* importance of two factors--transportation costs and the value of screenings--for the profitability of cleaning.

Figures 5 and 6 show an alternative view of these results. In each figure, the proportion of bushels cleaned, rather than supply of screenings, is measured along the vertical axis. Under base-case assumptions, the elevator cleans about a third of all bushels in 1990 (with screenings valued at $30 per ton). No cleaning occurs under base-case assumptions for 1987 (with screenings valued at $10 per ton), despite higher average levels of dockage.

Commercial Discounts

Another factor that can influence cleaning (and will likely be of increasing importance in the future) is specification of premiums or discounts. Premiums for cleaner wheat, or discounts for lots with dockage exceeding a particular level, though not pervasive in current trading practices, can induce more cleaning. For example, a buyer may specify, along with other contract terms, that a price discount applies if dockage exceeds some level. In fact, merchants have periodically used this strategy to procure HRS from country grain elevators.

Under these circumstances, the seller must analyze whether it is more profitable to accept the discount and avoid cleaning costs or to avoid the discount by cleaning to satisfy the contract limit. The answer depends on the magnitude of the discount, the maximum dockage limit, levels of dockage in the elevator's bins, and possibilities for blending.

Simulations were performed to provide insight into the effects of discounts. The goal was to determine, for a given set of contract terms, the "minimum discount" necessary to induce cleaning. To that end, a set of contract terms was specified (Table 5) with a price sufficiently high to attract a large share of the elevator's grain.[12] For experimental purposes, various maximum dockage limits were specified.

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[11]With lower beginning dockage levels, a larger volume of grain is cleaned in order to generate a given quantity of screenings.

[12]Although the model offers two blend contracts, only one was necessary for these simulations; the price for the second blend was lowered sufficiently to force it out of the solution.

Table 5:
Assumed Contract Terms for Evaluation of Discounts

Minimum Protein:	14 percent
Minimum Test Weight:	59 pounds
Maximum Dockage:	*
Maximum Damage:	1 percent
Maximum Defects:	3 percent

Contract Price
1987: $3.50 / bushel
1990: $3.10 / bushel

* Varied between 0.2 and 1.0 percent.

Calculating a "minimum discount" proceeds in two steps. First, the model is solved with a maximum contract limit for dockage. This yields a profit level for the elevator. Second, the dockage limit is relaxed,[13] and the contract price is lowered (by quarter-cent increments) until the same profit level is attained. The difference between the original price and the lower price (with relaxed dockage limit) is interpreted as the discount necessary to induce cleaning. If the discount were any smaller, the elevator would maximize profits by not satisfying the contract limit and absorbing the discount.

This procedure was followed for a range of contract limits under both sets of wheat quality conditions (i.e., 1987 and 1990). Results are shown in Figure 7. For both years, an inverse relationship is evident: the lower the dockage limit, the greater the discount necessary to induce cleaning. Discounts are larger under quality conditions of 1987, due to higher average levels of dockage and low screening values. Under 1990 quality conditions, discounts are required only to induce cleaning below 0.4 percent dockage. Some cleaning was profitable under base-case assumptions for 1990, even in the absence of discounts.

A "market solution" to the problem of excess dockage in U.S. exports would involve transmitting price discounts from foreign buyers to export firms and ultimately country elevators, in much the same way that premiums and discounts for other quality attributes (e.g., protein) are conveyed within the grain marketing system. The elevator model adopts a supply-side perspective, focusing on the firm's optimal response to price incentives. However, the demand for quality attributes also determines the value of quality attributes, as indicated in a companion study (Johnson and Wilson).

[13]In particular, the limit was inflated to 5 percent--higher than the dockage level in any of the elevator's bins.

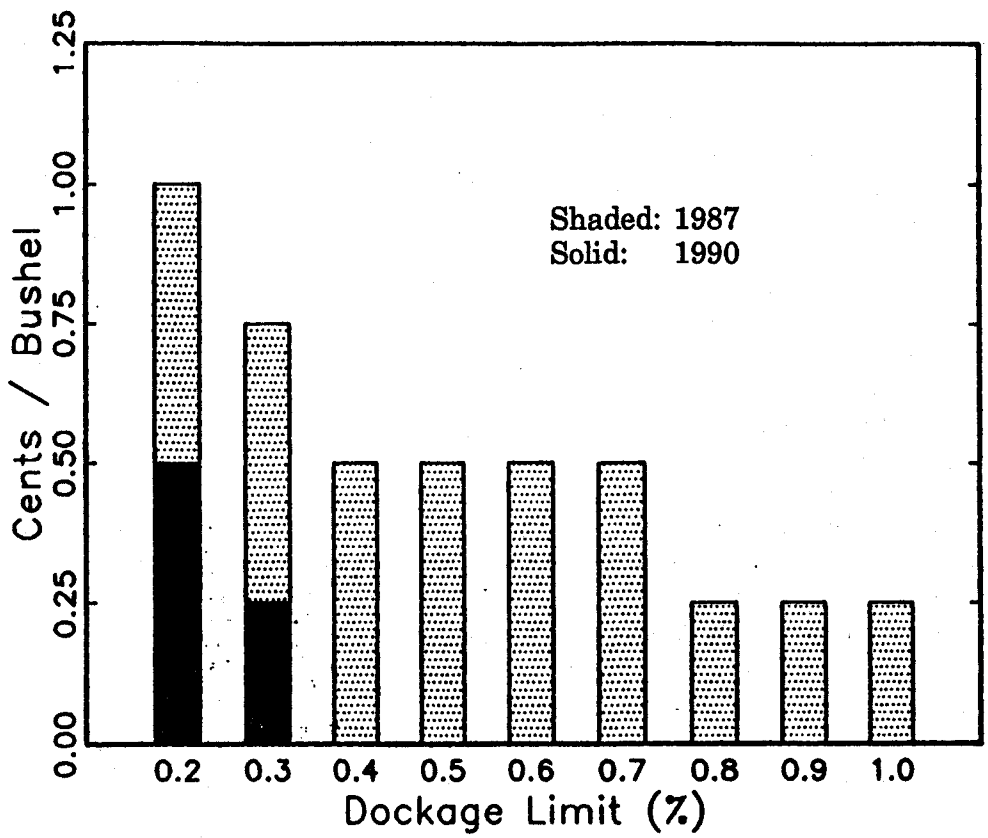

Figure 7:
Minimum Discounts Necessary to Induce Cleaning

Change in Grade Standards

It has been proposed that dockage be incorporated in the official grade standards for wheat.[14] In particular, a maximum limit of 0.5 percent dockage would be specified for grades #1-3, and a maximum limit of 2.5 percent dockage would be specified for grades #4-5. Limits for other grade factors would remain unchanged under this proposal. Proponents argue that, since foreign buyers typically specify grade #2 or better, the effect would be to lower average levels of dockage in U.S. wheat exports, thereby improving competitiveness.

The aggregate impacts of such a change (i.e., in terms of U.S. export revenue) are difficult to foresee. There is no assurance that foreign buyers would continue to specify the same U.S. grades after a change in standards. In fact, individual buyers--for whom dockage is not an important quality factor--might choose to specify lower grades than previously to take advantage of price differentials. This would lead to a reduction in other grade factors.

The elevator model can be used to demonstrate how a change in grade standards could affect a merchandising firm. For this purpose, simulations were conducted in which grain sales were confined to two possible blends[15] --the first identified with grade #3 contract limits and the second with grade #4 contract limits. This highlights the significance of the breakpoint in proposed grade limits for dockage (i.e., between grades #3 and 4).

Grade limits are reproduced in Table 6. Some grade factors (e.g., contrasting classes) are omitted from the analysis. Based on our assumptions about grain quality (Tables 2 and 3), all of the elevator's wheat would meet or surpass the *current* grade #3 limits (before inclusion of dockage).

**Table 6:
Wheat Grade Limits**

	U.S No. 3	U.S. No. 4
Minimum Test Weight (lbs.)	55.0	53.0
Maximum Damage (%)	7.0	10.0
Maximum FM (%)	2.0	3.0
Maximum SB (%)	8.0	12.0
Maximum Defects (%)	8.0	10.0
Maximum Dockage (%)	0.5*	2.5*

* Under proposed grade standards.

[14]Personal communication with FGIS.

[15]Rather than formally restricting quantities, prices for the two blends were set sufficiently high to attract all grain from the elevator's bins.

Our purpose is to estimate the cost to the elevator of including dockage as an additional grade factor, assuming that the elevator blends (and cleans) simply to meet grade limits.[16] Accordingly, simulations were conducted both with and without the indicated dockage limits. With grade 3 selling at a premium relative to grade 4, the elevator would sell all wheat (in either crop year) as grade 3 or better under current grade standards. With the introduction of grade limits for dockage, the elevator is induced to "upgrade" some of its wheat through cleaning--provided that a higher price for grade 3 more than offsets cleaning costs.

Price relationships are a crucial aspect of this problem. For illustrative purposes, simulations were conducted with different assumptions about the price difference between grades 3 and 4.[17] Results are displayed in Table 7.

Table 7:
Impact of Including Dockage as Grade Factor Limit

Price Difference	Current Grade Standards		Proposed Grade Standards	
Grade 3 - Grade 4	% cleaned	% sold as grade 3 or better	% cleaned	% sold as grade 3 or better
---1987 Crop Quality---				
2 cents	0	100	38	81
4 cents	0	100	52	100
---1990 Crop Quality---				
2 cents	28	100	28	100
4 cents	28	100	28	100

[16]In practice, it is uncommon for country shippers to blend to meet grade limits. More common is blending to meet limits for individual factors, which may not necessarily correspond with grade limits. Although the premise of these simulations is unrealistic, there are few alternatives for estimating the impact of a change in standards.

[17]It is not standard for commercial traders to quote prices for grades 3 and 4; rather, traders typically quote a price for grade 1, with discounts for individual factors. The difference in price between grades can thus depend on *which* factors deviate from grade limits. Discounts vary according to the factor and over time. (Scherping and Wilson).

The proposed change in grade standards would affect the extent of cleaning activity in 1987. Under existing grade standards and base-case assumptions, the elevator had no incentive to clean in that year. Introducing a dockage limit induces cleaning. Under new grade standards, the extent of cleaning in 1987 depends on the size of the price premium for grade 3: a larger premium induces more cleaning.

In contrast, the change in grade standards does not affect cleaning in 1990. Under base-case assumptions, the elevator had other incentives to undertake cleaning activities in that year and could satisfy the new grade standard for dockage without additional expense.

Thus the proposed change in standards would have a significant impact only in 1987. Additional costs of 0.7 cents per bushel (averaged over all bushels sold) would be incurred in 1987 so that all wheat could meet or exceed the grade 3 limits. These are net costs, taking into account the value of wheat loss due to cleaning, returns from sale of screenings, and transportation savings.[18] Assuming no change in sale prices, the net costs of satisfying new grade limits would be reflected in compressed margins or (more likely) passed along to producers as lower elevator bid prices.

In principle, the net impact of a change in standards would depend on what happens to price relationships, including market discounts for dockage and other grade factors. Although prices could be altered by a change in standards, these effects are difficult to predict.

V. Summary and Implications

Dockage in wheat is a non-grade-determining factor in the U.S. marketing system. In individual transactions, dockage is a contract term that is subject to negotiation between buyers and sellers. Other countries include the equivalent of dockage as a grade-determining factor with stringent limits. The configuration of grade limits (in conjunction with inter-grade price differentials) determines the incentives to clean in these countries. Similar proposals have been made in the United States. Specifically, the 1990 Farm Bill enables the Federal Grain Inspection Service (FGIS) to establish or amend grade standards with a view to match levels of "cleanliness" offered by competing countries.

This paper develops a mathematical programming model to analyze cleaning decisions at country elevators. The analysis incorporates a detailed model of cleaning costs and places cleaning activities within the broader framework of a blending and merchandising problem. By incorporating alternatives to cleaning, i.e., blending from different bins and shipping wheat without cleaning, the model provides a more realistic basis for assessing the impact of selected variables and for evaluating how alternative regulations would affect the economics of cleaning.

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[18]As noted previously, the model takes no account of investment costs, which are fixed from the point of view of a firm with cleaning equipment already in place. For elevators without such equipment, the prospective costs of a change in grade standards would be substantially higher.

Model parameters were chosen to represent a typical country elevator in North Dakota. Simulations were performed for two crop years, 1987 and 1990, to demonstrate the sensitivity of cleaning decisions to factors that vary through time. Of particular importance are the level and distribution of dockage and other quality characteristics in the crop, and the value of screenings. The year 1987 was characterized by a crop with greater dockage and lower screening values than was 1990.

The value of screenings and the price of transportation have an important influence on incentives to clean, and thus on the proportion of wheat that is cleaned before shipment. For each of our representative years, screening values greater than $20 to $25 per ton induced cleaning. Savings on transportation costs provide an additional incentive, particularly when high freight costs are combined with high screening values. Under our base-case assumptions for 1987, cleaning was profitable only for longer hauls, i.e., with freight costs in excess of $0.90 per bushel. In 1990, freight costs of approximately $.50 per bushel were sufficient to induce cleaning.

The level of discount (premium) necessary to induce additional cleaning before shipment was shown to vary from year to year. Under our assumptions for 1987, a minimum discount of 1/2 cent per bushel was necessary to induce cleaning down to 0.5 percent dockage. No such discounts were necessary in 1990 because of other incentives favorable to cleaning.

Cleaning wheat is a routine part of elevator operations in some parts of the United States, particularly in the spring wheat growing regions. Cleaning is purely a commercial decision at present, not affected by non-market regulations. Margins associated with cleaning reflect the cumulative impact of a number of variables, including the amount of inbound dockage, the value of screenings, and transportation costs. In addition, cleaning decisions may be influenced by contract terms such as premiums for cleaner wheat or discounts for lots with dockage exceeding a particular level. Though not pervasive in current trading practices, discounts for excess dockage can induce cleaning to satisfy the demands of individual buyers.

The effectiveness of using grade factor limits to induce cleaning would depend on numerous variables, as demonstrated in this paper. An important limitation is that, without equal factor limits being applied to all grades, elevators could choose to ship at grades with larger allowable limits for dockage.

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