United States
Department of
Agriculture

Economic
Research
Service

Agricultural
Economic
Report
Number 669

Economic Implications of Cleaning Wheat in the United States

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Lorna Aldrich, and David Pace

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Economic Implications of Cleaning Wheat in the United States. By Bengt T. Hyberg, Mark Ash, William Lin, Chin-zen Lin, Lorna Aldrich, and David Pace. Commodity Economics Division, Economic Research Service, U.S. Department of Agriculture. Agricultural Economic Report No. 669.

Abstract

The costs of cleaning wheat exceed the domestic benefits of cleaning wheat. The absence of net domestic benefits from cleaning wheat suggests that the U.S. wheat market is responding efficiently to domestic market signals for less dockage and foreign material in wheat. An overall reduction in dockage and foreign material could benefit the U.S. wheat industry only if cleaner U.S. wheat induces sufficient trade benefits to overcome the net domestic cost. Barring any benefits from increased sales and premiums on the international market, there is no basis for mandatory cleaning requirements in the United States based on the costs and benefits of cleaning wheat. The least-cost alternative of cleaning wheat is at the subterminal elevator, which had a $23 million net cost.

Keywords: Wheat, wheat quality, wheat markets, commercial elevators, grades and standards, grain cleaning

Acknowledgments

The authors appreciate reviews, suggestions, and contributions of Ed Allen, Brian Just, Mack Leath, Kristi McComas Steward, Stephanie Mercier, Patrick O'Brien, Tom Tice, Larry Van Meir, and C. Edwin Young (all from the Economic Research Service); John Giler, Marianne Plaus, and Dave Shipman (Federal Grain Inspection Service); Jasper Womack (Congressional Research Service); Tom O'Conner (National Grain and Feed Association); Brian Adam and Kim Anderson (Oklahoma State University); D. Demcey Johnson, Dan Scherping, and William Wilson (North Dakota State University); and the membership of the Grain Quality Steering Committee. Their efforts improved this report. The authors especially appreciate the assistance of Brenda Toland and Wanda Reed-Rose (Economic Research Service) in preparing this report.

1301 New York Avenue, NW.
Washington, DC 20005-4788

December 1993

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Summary

The costs of cleaning wheat exceed the domestic benefits. For cleaning wheat to be economically feasible, benefits from increases in premiums, or decreases in the trigger level for dockage deductions, or increases in U.S. wheat exports would have to reach at least $23 million to compensate for the additional costs of cleaning all U.S. export wheat at the least-cost location. The cost of cleaning this wheat would exceed $41 million, while the benefits would total nearly $19 million. Cleaning a smaller quantity would reduce the total net cost, but increase the per bushel cost.

The absence of net domestic benefits from cleaning wheat suggests that the U.S. wheat market is responding efficiently to domestic demand for less dockage and foreign material (FM) in wheat. Evidence from the domestic milling sector and results from U.S. Department of Agriculture (USDA) grain inspections and a commercial survey also support the conclusion that the domestic wheat marketing system is responding to the demand for cleaner wheat.

Domestic demand for cleaner wheat is limited because U.S. mills remove all nonmillable materials to meet sanitary requirements and avoid damage to milling equipment. Stricter internal standards require more advanced cleaning technology than would be feasible at commercial elevators. Cleaning costs at flour mills are virtually constant regardless of the levels of dockage and FM. Thus, cleaning wheat for delivery to domestic flour mills would be superfluous.

The cleaning practices by domestic flour mills provide little incentive to offer premiums for cleaner wheat. This has a strong effect on the domestic wheat market where few premiums are offered for cleaner wheat. The lack of premiums reduces the incentive to deliver low-dockage, low-FM wheat. Domestic mills and commercial elevators more frequently adjust payments by subtracting out the amount of nonwheat material or using price discounts.

Wheat becomes cleaner as it moves through the marketing system. Examination of surveys of commercial elevators and domestic flour mills and USDA grain inspection records indicates that cleaner wheat is delivered to export elevators than to flour millers, indicating that the current system of premiums and discounts is effective in directing cleaner wheat to locations, such as export elevators, that prefer additional cleanliness.

The subterminal elevator is the most cost-effective location to clean winter wheat because the larger volume handled permits the use of faster, more efficient cleaners and reduces the total capital expenditure required. Cleaning the same volume of wheat at country elevators would have a higher cost because the larger number of elevators would increase capital investment and economies of scale would be lost. Cleaning the same wheat at export elevators would be more costly because the price of wheat is higher at export terminals and export terminals tend to be located in cities. The higher wheat price increases the cost of wheat loss. Their urban location increases operating costs and lowers the revenue from the sale of screenings. The per bushel gross cost of cleaning averages 4 cents for winter wheat at the least-cost location (subterminal elevators); the cost is higher at country elevators, reaching nearly 7 cents for winter wheat. Per bushel domestic benefits of cleaning averages around 2 cents for winter wheat at subterminal elevators and 3 cents for winter wheat at country elevators.

The least-cost location to clean spring wheat (hard red spring and durum) is the country elevator, because these facilities already have and use efficient disc-cylinder

cleaners, and the country elevators in the spring wheat regions frequently ship directly to the export terminal. The per bushel gross cost of cleaning averages less than 2 cents for spring wheat at the country elevators. The cost is higher at export elevators, reaching nearly 4 cents. Per bushel domestic benefits of cleaning averages less than 0.5 cents at either location.

White wheat differs from both winter and spring wheats because it is rarely cleaned, country elevators handling white wheat do not have much wheat cleaning equipment, and it is grown a short distance from export terminals. For these reasons, the least-cost location for cleaning white wheat was ambiguous. Net costs were estimated to be equal at both country elevators and export terminals. The per bushel cost of cleaning white wheat is approximately 4 cents. The per bushel domestic benefit from cleaning white wheat is less that 1 cent.

Wheat loss, the economic loss associated with removing sound wheat and material saleable as sound wheat during cleaning, is the largest operating cost item of cleaning wheat--accounting for up to 85 percent of total cleaning costs. Other cost items include fixed, energy, and labor costs.

Sales of screenings and savings in transportation costs are the two largest domestic benefits from cleaning wheat, accounting for about 87 percent of the benefits (67 percent screenings sales and 20 percent transportation savings). Other potential benefits include lower energy and fumigation costs and reduced storage losses from insects and other agents.

If all nonfeed wheat were cleaned rather than just export wheat, the net loss would rise to $53 million. Although the total benefits increase to $37 million, the total cost jumps to $91 million, more than offsetting these gains. Although the net cost per bushel decreases, the increased volume results in the higher net loss.

Economic Implications of Cleaning Wheat in the United States

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Lorna Aldrich
David Pace

Introduction

Wheat exported from the United States does not always match the *cleanliness*[1] of wheat exported by two of its major competitors, Canada and Australia. Members of Congress and some in the wheat industry are concerned that the United States may be losing wheat export markets because these competitors are offering wheat for sale that is cleaner than U.S. wheat. Some observers contend that cleaner U.S. wheat would make the United States more competitive in international markets. Others contend that matching the cleanliness of Canadian and Australian wheat, either through mandated standards or other means, would raise costs for producers or elevators and exceed any market price *premium* for cleaner wheat. The result of additional cleaning would be higher U.S. export prices and loss of sales in price-sensitive markets.

Congress has recognized that the information now available is insufficient to support either claim.[2] Section 2005 of the Grain Quality Title of the Food, Agriculture, Conservation, and Trade Act of 1990 (FACTA) requires the U.S. Department of Agriculture's (USDA) Federal Grain Inspection Service (FGIS) to establish or amend *grain grades and standards* to include "economically and commercially practical levels of cleanliness" for grain to meet the requirements of *grade* U.S. No. 3 or better. Prior to implementing any changes in cleanliness standards, however, FGIS is required to conduct a comprehensive commodity-by-commodity study of technical constraints and economic costs and benefits associated with any such changes. Studies are to be conducted for wheat, corn, soybeans, sorghum, and barley.

USDA's Economic Research Service (ERS), in cooperation with researchers at land-grant universities and the U.S. grain industry, is conducting the commodity-by-commodity studies in fulfilling part of the congressional mandate. This report will determine the domestic costs and benefits of cleaning wheat to a standard comparable with our major export competitors. In this study, wheat cleanliness is defined and the domestic benefits and costs of cleaner wheat are identified and quantified. How the competitive position of the United States in international wheat markets would be affected by marketing cleaner wheat is assessed in a companion report, *The Role of Quality in Wheat Import Decisionmaking*. Appendices present more detailed information about data used in this study and results by class of wheat.

Structure of the Study

This study begins by defining wheat cleanliness and examining the role of cleanliness within the larger concept of wheat quality. The terms "cleanliness" and "quality" are sometimes interchanged in the debate over the need for higher standards of cleanliness, but cleanliness is only one of many attributes that determine quality. Wheat quality includes all wheat characteristics, such as cleanliness, protein content, protein quality, and test weight, that are important to buyers. Wheat cleanliness is defined by the amount of nonwheat material in wheat. Domestic and foreign demand for wheat is determined by the effect of all these attributes on the performance of the wheat in its final use, in addition to nonquality factors, such as price, government trade relationships, and credit availability.

[1] Italicized words are defined in the glossary at the end of the report.

[2] Senators Daschle (D-S.D.) and Bond (R-Mo.) introduced the Grain Quality Incentive Bill of 1989 (S. 1977) in November 1989 and followed with hearings. A substantially revised version was adopted in the Senate's 1990 farm bill (S. 2830). The House of Representatives included similar grain quality provisions in its 1990 farm bill (H.R. 3590). A House-Senate joint conference committee adopted the grain quality provision as Title XX of the Food, Agriculture, Conservation, and Trade Act of 1990 (P.L. 101-624).

Cleanliness is only one of many quality factors which influence buyers' demand for wheat. While some buyers are seeking cleaner wheat, other buyers are more concerned about the protein content, gluten quality, or color of the wheat. Changing the U.S. grades and standards to require higher standards of cleanliness is one proposal that has been made for raising the cleanliness level of U.S. wheat in order to increase exports. The U.S. grades and standards offer a partial measure of quality because they measure physical characteristics, such as damaged kernels or the presence of *nonmillable material*, but they do not measure intrinsic characteristics, such as protein, or the uniformity of grain between shipments and within a shipment. Official grades and standards also affect market behavior because they sometimes serve as a basis for contract specifications.

Because the costs of cleaning wheat exceed the domestic benefits and buyers' quality needs can be met outside the U.S. grades and standards through contract specifications or familiarity with the characteristics of wheat by variety and region, this report does not provide support for changing the U.S. grades and standards.

The Food, Agriculture, Conservation, and Trade Act of 1990 explicitly directs FGIS to implement tighter grain standards regarding cleanliness if such change would:

1. "enhance the competitiveness of exports of wheat, ... from the United States with wheat, ...exports by other major exporters";

2. "result in the maintenance or expansion of the United States export market share for wheat,...";

3. "result in the maintenance or increase of United States producer income"; and

4. "be in the interest of United States agriculture, taking into consideration technical constraints, economic benefits and costs to producers and industry, price competitiveness, and importer needs."

The next section examines the economics of cleaning wheat. The demand for cleaner wheat depends on the prices the final users of wheat are willing to pay, reflected back through the marketing chain to the farm. Each point between the final user and the farmer is a market, which is connected to the other markets by wheat prices. The supply of cleaner wheat depends on the effect of cleaning on the costs of producing and/or delivering wheat to the next stage in the marketing chain.

The section "Options for Wheat Cleaning Within the Production-Marketing System" examines the options available for cleaning grain at each point along the marketing chain and the economic incentives facing each agent. Farmers have the option of altering production and/or harvesting practices or cleaning wheat. Commercial elevators can meet buyer specifications by using premiums to acquire cleaner wheat, placing *discounts* on nonwheat material to discourage "dirty" wheat, or cleaning wheat. Flour mills clean all wheat they receive.

The remainder of the report looks at the costs and benefits of cleaning wheat. Individual factors that determine the costs and benefits of cleaning grain include the capacity and efficiency of equipment, wheat lost during cleaning, and the volume of wheat that can be processed at each stage of the marketing/distribution system. The domestic benefits include transportation savings, sales of the material (*screenings*) removed from the wheat (an offset to *wheat loss*), savings in handling costs, and potentially larger premiums/smaller discounts from buyers.

The individual factors determining demand and supply of cleaner wheat are then evaluated at different points along the marketing chain. The report concludes by aggregating the estimated costs and benefits at each point and evaluating the alternatives available for providing cleaner U.S. wheat.

Several important conclusions emerge from this report:

- U.S. wheat becomes cleaner as it moves along the marketing chain.

- Domestic millers clean all wheat and therefore rarely offer premiums for clean wheat.

- Because U.S. millers generally do not offer premiums, there is little incentive to clean wheat for domestic nonfeed use.

- The marketing system differentiates between end-users, delivering cleaner wheat to export elevators than to domestic millers.

- The production and marketing characteristics of different wheat classes make the least-cost cleaning location different for different wheat classes.

- Aggregate costs are minimized by cleaning winter wheat at subterminal elevators and spring wheat at country elevators. The least cost location to clean white wheat was ambiguous with the same estimated net cost for country elevators and export terminals. However, these costs exceeded domestic benefits in all cases.

- Substantial benefits from the export market would be required to make widespread additional cleaning beneficial to U.S. wheat producers and marketers.

The Role of Cleanliness in Wheat Quality

Cleanliness is only one characteristic among many which determine wheat quality (see box on wheat quality). The full range of physical and intrinsic characteristics, as well as the uniformity of these characteristics, determines the suitability of wheat for any given end-use. Because wheat has a wide range of diverse uses, the adoption of any single measure or set of measures of wheat quality is likely to satisfy only a segment of the market.

Wheat cleanliness is defined by the amount of nonwheat material contained in a given shipment of wheat. This nonwheat material has two components: *dockage* and *foreign material* (FM). Dockage is nonwheat material, such as weed seeds, chaff, stems, and stones, that can be readily removed through cleaning because its weight or size is different from wheat. Foreign material is nonwheat material that is harder to remove because its weight, size, and shape resemble that of wheat.[3] Both dockage and FM are considered nonmillable material by flour millers. Millers also consider *shrunken and broken kernels* to be nonmillable material. This study focuses on dockage and FM as cleanliness characteristics. However, wheat cleaning removes dockage, FM, and shrunken and broken kernels.

The Role of Cleanliness in the U.S. Grades and Standards

Changing U.S. grades and standards by combining two measures of cleanliness, FM and dockage, into a single grade-determining factor would neither facilitate U.S. wheat exports nor serve as an incentive to reduce dockage and FM in U.S. wheat (Mercier, 1989).[4] The United States is one of only a few countries that report dockage and foreign material as separate measures in the official export inspections. Most other countries combine all nonwheat material into a single measure, foreign material. However, the important issue with regard to cleanliness is how nonwheat material is measured, not the name given to it (see box on Recent Changes in Grain Grading and Standards).

U.S. wheat exports are required to be officially inspected against a set of standard factors that are useful in determining wheat quality and cleanliness (table 1). This is not true for wheat sold in the domestic market. U.S. end-users tend to specify a subset of these factors as percentages rather than the full set of factors as a grade in their purchase contracts. The grades and standards play a more obvious role with U.S. wheat exports than they do in the domestic market. U.S. grain grades and standards specify tolerances for a set of characteristics related primarily to grain's physical condition. These standards do not include most intrinsic characteristics. In the case of wheat, the grades and standards provide two measures of cleanliness: dockage and FM. FM is a *grade-determining factor*, while dockage is reported on inspection certificates but does not affect the grade. For example, a wheat shipment grade U.S. No. 2 has no more than 0.7 percent FM, but could have any dockage content.

The more fundamental issue surrounding the debate on the treatment of dockage in the U.S. wheat grades and standards hinges on foreign buyers' ability to freely specify and receive wheat of desired quality in contracts without any impediments. If buyers can do so, recording wheat's dockage content in export certificates may be a sufficient measure to facilitate transactions between buyers and sellers. The evidence available indicates that importers of U.S. wheat can and are specifying maximum acceptable dockage levels, and penalties are assessed if wheat fails to meet these standards (Mercier, 1993; Adam and Anderson, 1992).

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[3]Not all dockage and FM are treated in the same manner. Certain particularly objectionable materials, such as glass, stones, toxic weed seeds, animal filth, and toxic substances, are noted specifically during the inspections. Only small tolerances are allowed for these substances, before the wheat is classified as sample grade under U.S. grades and standards.

[4]Names in parentheses refer to sources listed in the References at the end of this report.

Wheat Quality

Wheat is not a homogeneous product. The United States produces five major classes of wheat and a large number of genetic varieties within each class. Each class and variety has different end-use characteristics. These wheat varieties are grown across the United States under a large number of growing conditions, introducing additional variations in their end-use properties. Complicating matters even further is the fact that wheat has many diverse end-uses, such as bread, crackers, pasta, and animal feed. Each of these uses requires wheat with a specific set of end-use characteristics. The ultimate test of wheat quality for each use lies in its performance in producing the final product.

Wheat quality can be described as having three dimensions: (1) physical condition, including purity and soundness, (2) intrinsic characteristics, and (3) uniformity (fig. 1). Each of these characteristics affect wheat's performance in terms of its processing and end-use properties.

Purity measures the amount of dockage, FM, and other aspects of wheat's wholesomeness, including pesticide residue, live insects, and toxic weed seeds. Soundness measures defects, including damaged kernels, heat-damaged kernels, total defects, and shrunken and broken kernels. Test weight and moisture content are also included as measures of soundness because test weight provides an indication of likely milling yields and the moisture content affects wheat's storability. Damaged kernels are correlated with lower test weight and lower milling yields.

Intrinsic characteristics are the biochemical and structural properties inherent in the wheat. Important intrinsic characteristics for wheat include protein content, gluten quality, hardness, color, fat acidity, crude fiber, and ash. Measuring these intrinsic characteristics of a wheat can be difficult and time consuming. Requirements for intrinsic attributes differ by end-use. Flour used to make bread, for example, requires hard wheat with a high-protein content, whereas wheat flour used to make crackers or cakes must have less protein, which is available from soft wheat (fig. 2). Baking properties of flour could be affected by gluten qualities even when the protein content is the same.

Uniformity refers to the degree of variation in wheat quality, either physical or intrinsic, within a shipment and between shipments. Fine materials in bulk grain naturally segregate during shipment by gravitating to the bottom middle of the grain vessel. When discharged, the entire cargo is rarely reblended into separate sublots for each buyer. Lack of uniformity frequently is a source of disputes because wheat in a shipment can be shared by several different buyers. Variation in wheat quality between shipments can cause disruption to buyers' milling operations. Blending or mixing wheat varieties also affects uniformity--the larger the number of wheat varieties, the less uniform the quality.

The wide range of quality characteristics and end-uses increases the difficulty in effectively improving wheat quality. Identifying the characteristics that potential customers seek is important. The effect of improving one aspect of wheat quality needs to be viewed in the light of other characteristics of the wheat and the desired end-use. For example, if U.S. wheat is viewed as clean by a potential customer, cleaning it further will not significantly improve the customer's evaluation of its quality. Similarly, if that potential customer views U.S. wheat as inadequate for some reason other than cleanliness, then cleaning wheat diverts attention from the improvements that might enhance U.S. wheat's prospect in that market. In addition, cleaning wheat could increase the cost of producing the wheat.

Recent Changes in Grain Grading and Standards

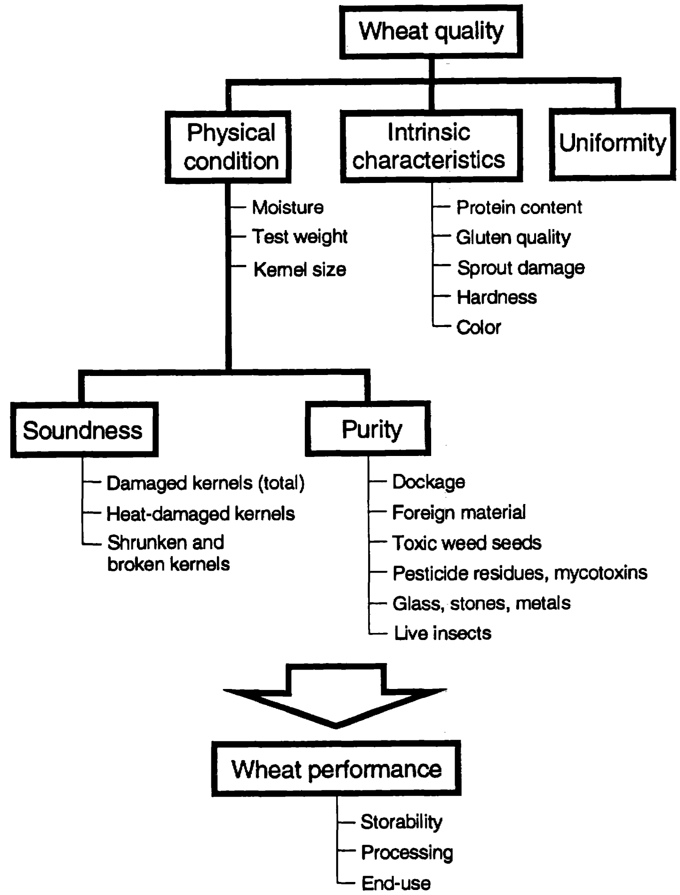
The Grain Quality Improvement Act of 1986 prohibits the reintroduction of dust or foreign material once it has been removed. This law does not prevent leaving nongrain material in grain or preclude blending of different lots of grain containing various levels of nongrain material to achieve the maximum allowable percentage.

In 1987, FGIS began to report dockage to the nearest tenth percent instead of rounding down to the nearest half percent. This ended the possibility of a certificate stating zero dockage but in fact allowing the wheat to contain up to 0.49 percent dockage.

Title XX of the Food, Agriculture, Conservation, and Trade Act of 1990 requires that USDA review standards for grain entering the Farmer-Owned Reserve to encourage higher quality grain to enter the program. As of the 1991 crop, the Secretary of Agriculture must also establish premiums and discounts related to cleanliness and other grain qualities for the price support program. In addition, the law requires that USDA establish minimum quality standards for grain stored for the Commodity Credit Corporation (CCC). The new standards should consider factors related to the grain's storability and assurance of acceptable end-use performance. The CCC will use FGIS approved procedures to inspect and evaluate the grain's condition.

Figure 1

Wheat quality dimensions



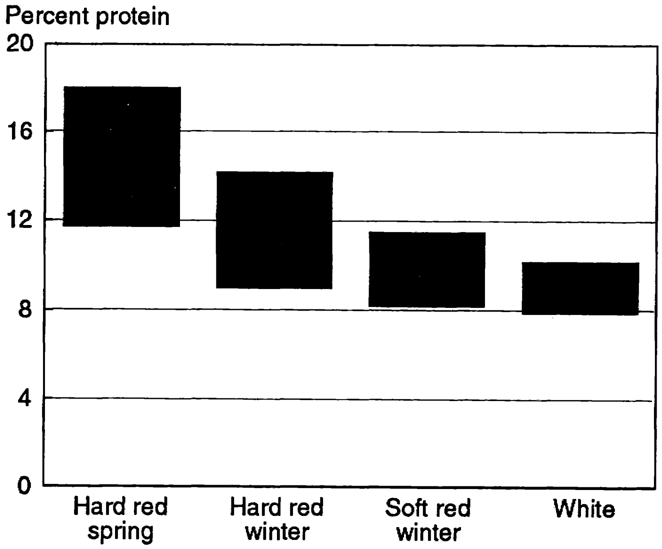
Source: Adapted from the National Wheat Improvement Committee.

The Economics of Cleaning Wheat

The value of wheat is derived from the contribution it makes to the value of a wide range of final products. Wheat characteristics that increase the value of an end product or reduce the cost of producing a finished product will increase the value of that wheat. Conversely, characteristics that increase processing, handling, storage, and transportation costs lower the value of wheat. End-users employ price discounts and premiums, weight deductions, and contract specifications to communicate the value of wheat characteristics to their operations.

Discounts and premiums on end-use characteristics move the wheat market. If a characteristic has the same value to all participants in the wheat market, then the price adjustments would be expected to be consistent across the market. Often these characteristics are found in government grading standards. If a characteristic has a different value to end-users, one would expect the marketplace to direct wheat with that specific characteristic to those end-users who wanted it, and away from those who are indifferent or find the characteristic to be undesirable (see box on the wheat marketing chain). If the discounts and premiums are transmitted undistorted from end-users to the farm, the farmers

Figure 2
Protein range and flour uses of major wheat classes



Flour uses:

- *Used to blend with weaker wheats for bread flour
- *Whole wheat bread, hearth breads
- *White bakers' bread, bakers' rolls
- *Waffles, muffins, quick yeast breads, all-purpose flour
- *Noodles (oriental), kitchen cakes and crackers, pie crust, doughnuts, cookies, foam cakes, very rich layer cakes

Note: Flour uses are approximate levels of protein required for specified wheat products. Durum is not shown because it is not traded on the basis of protein content.
Source: Joy L. Harwood, Mack N. Leath, and Walter G. Heid Jr., 1989.

Table 1--Official U.S. Department of Agriculture Grades and Standards for wheat

			Maximum limits of:						
			Defects					Wheat of other classes[1]	
Grades[2]	Hard red spring wheat or white club wheat[3]	All other classes	Heat-damaged kernels[4]	Damaged kernels (total)	Foreign material	Shrunken and broken kernels	Defects (total)[5]	Contracting classes	Wheat of other classes (total)[6]
	Pounds		*Percent*						
1	58.0	60.0	0.2	2.0	0.4	3.0	3.0	1.0	3.0
2	57.0	58.0	.2	4.0	0.7	5.0	5.0	2.0	3.0
3	55.0	56.0	.5	7.0	1.3	8.0	8.0	3.0	10.0
4	53.0	54.0	1.0	10.0	3.0	12.0	12.0	10.0	10.0
5	50.0	51.0	3.0	15.0	5.0	20.0	20.0	10.0	10.0

[1] Unclassed wheat of any grade may contain not more than 10 percent of wheat of other classes.
[2] There is a limit of 31 insect damaged kernels per 100 grams.
[3] These requirements also apply when hard red spring wheat or white club predominates in a sample of mixed wheat.
[4] Includes heat-damaged kernels.
[5] Defects included damaged kernels (total), foreign material, and shrunken and broken kernels. The sum of these three factors may not exceed the limit for defects for each numerical grade.
[6] Includes contrasting class.

U.S. sample grade:

(a) Does not meet the requirements for the grades U.S. Nos. 1, 2, 3, 4, or 5; or

(b) Contains 32 or more insect-damaged kernels per 1,000 grams of wheat; or

(c) Contains four or more stones or any number of stones that have an aggregate weight in excess of 0.2 percent of the sample weight, any piece of glass, three or more crotalaria seeds (Crotalaria spp.), two or more castor beans (Ricinus communis L.), and two or more rodent pellets, bird droppings, or equivalent quantity of other animal filth per 1,000 grams of wheat; or

(d) Has musty, sour, or commercially objectionable foreign odor (except smut or garlic odor); or

(e) Is heating or otherwise of distinctly low quantity.

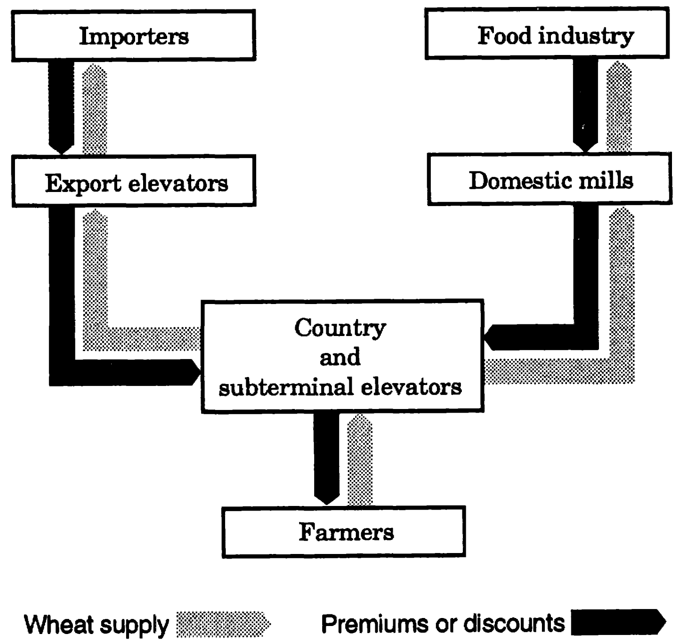
The Wheat Marketing Chain

Wheat moves through a complex marketing chain. Throughout the chain, premiums and discounts are used to communicate the demand and supply of wheat characteristics.

End-user demand for wheat cleanliness (and other characteristics) might be transmitted through three or more intermediaries before this demand reaches the farmer (fig. 3). End-users, either importers of U.S. wheat, domestic flour millers, or even feedlot operators, signal their demand for clean wheat by offering prices that incorporate premiums and discounts for different levels of dockage and FM. Elevators and farmers view these prices and respond to the option that maximizes their net returns. Transportation and handling costs serve to differentiate markets. Thus, most farmers cannot sell directly to an export elevator or flour mill, and often do not see the prices offered from these operations.

At the same time, the supply of "clean" wheat moves through these same intermediaries to the end-user. At each point along the marketing chain, the supply and demand for wheat cleanliness are brought into equilibrium, as the agents select the opportunity that maximizes their profit. By bringing the market into equilibrium, these operations serve an important function; however, they may mute the signals between farmers and end-users.

Figure 3



Notes: Some small direct flow to feedlots and mills from farmers exists.
Many country and subterminal elevators exist. Wheat flows between elevators before going to the mills or export elevators.

would be expected to respond by producing wheat with the characteristics in demand.

The amount of nonwheat material in a shipment affects exporters, millers, handlers, and farmers in different ways. Therefore, each agent will have a unique response to nonwheat material in wheat. Domestic flour mills and export elevators are the two final U.S. destinations for nonfeed wheat at the end of a complex marketing chain. At both destinations, the interest in cleanliness is its effect on the cost of obtaining and processing wheat into flour. Prices and contracts are used to communicate the effect of cleanliness on these costs between the many potential handlers. Thus, each step in the marketing and distribution chain constitutes a market for cleanliness, with demand at each step largely derived from the end-users' demand, or at least intermediate handlers' interpretation of them, and the supply and cost factors that apply at the intermediate level.

Domestic Flour Mills

Because U.S. flour mills clean all wheat prior to milling they have little incentive to offer premiums for cleaner wheat. U.S. flour mills clean wheat to assure that the wheat milled is virtually free from nonwheat material and shrunken and broken kernels, both to meet sanitary standards and to protect milling equipment from damage caused by milling hard nonmillable material. Flour mills use a combination of cleaners to remove nearly all dockage, FM, and shrunken and broken kernels (see box on wheat cleaning at flour mills). A survey of U.S. flour mills indicates that mills cleaned wheat to an average of 0.03-percent dockage and 0.02-percent FM at the first break (app. table 3), a level of cleanliness unavailable from other sources. The cost of removing additional dockage during the mill's stringent cleaning process is very small.

The concern flour millers have with wheat cleanliness is determining the quantity of millable wheat. They can address this concern by paying for only the wheat content

Wheat Cleaning at Flour Mills

Flour millers differ from grain elevators and other end-users in part because cleaners are an integral part of the entire milling process. This allows the mills to employ advanced technology that would be impractical at commercial elevators. The milling process is set up to remove weed seeds, other grains, sticks, stones, dirt, and other nonmillable material in early stages of the milling.

The types of cleaners used include scalpers or screeners, aspirators, magnetic separators, disc separators, and others. Scalpers or screeners are used by the mills to remove large material by segregating nonwheat material from wheat according to the size of particle. Aspirators remove light material by segregating this kind of nonmillable material from wheat according to particle weight. Magnetic separators are used to remove any metal from the grain. Disc separators are used to remove barley, oats, shrunken and broken kernels, and other FM. The combined use of these cleaners permit the mills to remove dockage, FM, and shrunken and broken kernels to a minimum level.

in shipment. Net weight purchases are a common practice used by flour mills.

Additional economic considerations, such as storage losses and transportation savings from cleaner wheat, do not carry as much weight with domestic flour mills as with commercial elevators or export terminals. Flour mills have little storage capacity in proportion to their milling capacity. Thus, with relatively few storage losses, mills have little incentive to pay higher prices to avoid cleanliness-related losses from insects, mold, and other agents that can occur during storage. In addition, elevators generally pay the transportation costs to domestic flour mills, and on the infrequent occasions when flour mills do pay, the flour mills are often located near the wheat-producing regions, reducing the potential savings from lower transportation costs.

The economic considerations help explain why wheat delivered to flour mills contains more dockage and FM than that delivered to export elevators (app. tables 1 and 7). The lack of premiums for cleaner wheat offered by flour mills limits any potential benefits of wheat cleaning by elevators.

Export Elevators

Export elevators communicate importer demand for U.S. wheat quality using prices and contract specifications. Importers also use prices and contract specifications to indicate their demand for wheat quality to wheat exporters. Export elevators meet these specifications both by acquiring grain that meets the specifications and by cleaning.[5] Export elevators acquire the amount and quality of wheat to meet importer demand and arrange the transport of this wheat to the export elevator. The cost of these activities is incorporated into the final cost to the importer. The wheat is purchased from country and terminal elevators. Once at the export elevator, the wheat is stored by class and quality characteristics. The export elevators then assemble shiploads that meet the contract specifications through *blending* or cleaning (see box on wheat blending). The official inspection takes place as the ship is being loaded.

Because export elevators act as agents for importers of U.S. grain, export elevators communicate importer demand for cleanliness to country and *subterminal elevators*. This demand encompasses the same factors noted for domestic millers, but includes concerns associated with transporting, handling, and storing wheat. Wheat going overseas must be shipped longer distances than wheat going to domestic flour mills, offering greater potential transportation savings from reducing the nonwheat material in the shipment. Similarly, wheat for export is generally stored longer than wheat for domestic use. The longer storage period can increase the risk of losses in storage due to insects, mold, and other agents, particularly if the wheat is shipped to or through the tropics. The increased risk indicates higher potential savings from reducing storage losses. Clean wheat is less susceptible to storage losses, providing a means to

[5]Export terminals can either be independent operations or owned and operated by a grain-exporting company. The discussion here is simplified by attributing all functions to the export elevator.

Wheat Blending

As wheat is delivered to the export elevator, it is assembled into shiploads by combining different lots of wheat into a shipment that, on average, meets the contract specifications. For instance: if the contract calls for 100 tons of wheat containing a maximum of 1.0-percent FM and 0.8-percent dockage, then the elevator can combine two 50-ton lots with 1.1-percent FM and 0.9-percent dockage, and 0.9-percent FM and 0.7-percent dockage to satisfy the contract. By combining the two lots, the end result would be a 100-ton shipload containing 1.0-percent FM and 0.8-percent dockage.

The actual process is much more complicated, however. Multiple factors, such as protein, moisture, FM, and others may also be required to meet the contract specifications. The objective of any firm is to maximize their net revenue from sales of wheat and screenings, net of cleaning and shipping costs. They can accomplish this by either selling the grain directly, or by blending, cleaning, or some combination of each. Given constraints on storage space, loadout capacity, and the delivery schedule, there are many possible outcomes. See Johnson and others (1992) for a theoretical simulation of this decision process.

capture these potential savings. Also included in the preferences communicated by export elevators are constraints imposed by importers or their governments, such as screening disposal, dust control regulations, and additional import duties associated with dockage.

Country and Subterminal Elevators

Commercial elevators balance the supply and demand for clean wheat. The willingness of domestic flour millers and exporters to pay for wheat cleanliness, and the cost of supplying cleaner wheat, is balanced at grain elevators. The movement of wheat from the farm takes place through the interaction of country, subterminal, and export elevators. Country and subterminal elevators store, sort, aggregate, and condition the wheat. Again, the cost of these activities is incorporated into the price of wheat.

Grain merchandisers direct wheat of the desired quality and cleanliness to the appropriate destination by employing and responding to the premiums, discounts, and contract specifications offered. The elevators create their market niche by responding to differences in demand for different grain characteristics. They obtain and supply uniform shipments of wheat according to each buyer's specifications and offer price, obtaining much of their operating margin by using the discounts and premiums in the markets when assembling these shipments.

The major difference between country elevators and terminal elevators is their source of wheat. Country elevators get most of their wheat directly from farms and transport it to domestic flour mills and/or subterminal elevators. Often, country elevators are cooperatives, owned and run by its farmer members. These elevators handle volumes that range from several thousand to several million bushels of wheat each year. Subterminal elevators tend to be larger than country elevators, purchase wheat primarily from other elevators, and have a higher ratio of volume handled to storage capacity.

Country and subterminal elevators have the same basic economic incentives influencing their demand for and provision of cleaner wheat. The differences in the incentives facing an elevator are largely due to its customers and the source of the elevator's wheat. Elevators that deal with export terminals will tend to face a demand for cleaner wheat that reflect the effects of nonwheat material on transportation and storage costs. These elevators will in turn use price incentives to acquire wheat that satisfies this demand. Alternatively, these elevators may find it more profitable to meet the demand for cleaner wheat by cleaning the wheat at the elevator. The variables entering this decision include the incentives involved, the volume to be cleaned, cleaning costs, and markets for the screenings. The decision-making process will be discussed in more detail in the section "Options for Wheat Cleaning Within the Production-Marketing System." Elevators serving primarily domestic flour mills will have little incentive to clean wheat because the flour mills generally do not offer premiums for low-dockage wheat, and in many cases, do not specify dockage limits in their purchase contracts.

Farmers

If there is no discount for dockage, dockage is not measured, or if the elevator deducts a standard dockage level from all farm deliveries, there is no incentive for farmers to deliver clean wheat. In fact, these conditions will create incentives for farmers to deliver higher dockage wheat, because in these cases, farmers can sell their dockage for the price of wheat.

For farmers, the demand for cleaner wheat comes from the elevators in their areas. Farmers observe the price differential between "clean" and "dirty" wheat and decide which to deliver. Farmers can deliver cleaner wheat by reducing weeds, altering crop rotations, changing harvesting practices, or cleaning the wheat. Each of these options has a cost (see section "Determinants of Costs and Benefits of Cleaning Wheat"). As with elevators, the decision is made based upon which option offers the highest profit.

Additional considerations for farmers include whether the wheat is to be delivered to the elevator at harvest or stored onfarm, and the effect of weather on wheat cleanliness. If farmers plan to store the wheat themselves, storage losses become a consideration, which might lead them to lower dockage levels. On the other hand, uncertain weather conditions, which can limit the effectiveness of altering production practices to obtain cleaner wheat, may reduce a farmer's incentive to incur higher production costs.

The Cleaning Decision

Wheat is cleaned when a farmer or elevator finds cleaning the most profitable option. As wheat moves from farms to country elevators to terminals, the producer or handler must consider whether the price incentives for cleaner wheat justify wheat cleaning. At the same time, end-users or their intermediaries must examine the price incentive necessary to acquire cleaner wheat and decide whether they can best satisfy their demand for cleaner wheat by cleaning or purchasing cleaner wheat.

The presence of discounts and premiums indicates that at least some buyers view increases or decreases in the amount of nonwheat material in wheat as having an economic effect. The presence or absence of discounts and premiums is evidence of the economic value of cleaner wheat at certain points in the marketing chain.

The presence of a grain cleaner and its efficiency affect decisions to buy cleaner wheat or clean wheat. Buyers who have an efficient grain cleaner would be expected to place a lower value on wheat cleanliness than buyers with an inefficient or no cleaner. Handlers with efficient cleaners have the option of cleaning wheat when the premium exceeds their variable cleaning costs, and buying clean wheat when it does not. However, they must incur the ownership and operating costs of wheat cleaning. Grain merchandisers without cleaners avoid ownership and operating costs, but they must discount dockage and FM enough to obtain clean wheat for their customers.

Options for Wheat Cleaning Within the Production-Marketing System

The profitability of cleaning wheat differs among the participants in the U.S. production and marketing system. At each point along the wheat marketing channel, the participants examine the economic incentives and determine the level of wheat cleanliness appropriate for their operation. These incentives were described in the preceding section. This section examines the options for providing cleaner wheat at different points along the production-marketing chain.

At the Farm

Farmers can provide cleaner wheat. However, because the measures that improve cleanliness affect production costs and grain yield, it is not clear that farmers will benefit by adopting them. More field studies would be needed to quantify the full economic effects of producing low-dockage wheat. In a wheat producers' survey, 81 percent of the respondents said they could not deliver cleaner grain by changing harvesting and handling practices without incurring additional costs. Producers indicated that it would cost them less to reduce dockage by changing harvesting practices than by changing production practices or using cleaners. Yet, 61 percent of farmers said they delivered wheat with dockage of 1 percent or less.

Farmers have a wide choice of methods to supply cleaner wheat. They can alter their production and harvesting practices, clean trucks, augers, and storage bins before use, and mechanically clean wheat to a targeted level of dockage and FM.

Production Practices

Changing production practices can lower dockage and FM levels in wheat by:

- Reducing the amount of weeds growing with the crop.
- Reducing exposure to insects.
- Lowering the incidence of disease.

Reducing exposure to these agents would result in fewer weed seeds, grain husks, and damaged grain being harvested with the wheat.

Weeds and disease can be reduced by planting with *certified seed*, altering *crop rotations*, increasing chemical applications, or increasing cultivation prior to planting. Each of these techniques has advantages and disadvantages. Altering the sequence of crops on a field breaks the life cycle for some pests, and can reduce the likelihood of weeds, insect pests, and diseases. Planting only certified seed reduces the reintroduction of weed seeds. Crop rotations can often reduce chemical costs and raise annual wheat yields. However, in some regions such as the Great Plains, there are often few alternative commercial crops available. In these situations, wheat-summer fallow crop rotations are a common practice.

Dockage and FM levels in wheat can also be reduced by proper chemical (pesticide and fertilizer) applications. While chemical applications can increase wheat yields by reducing insect losses and competition with weeds, each application raises production costs. An additional consideration regarding the application of pesticides is the increasing concern over the potential presence of pesticide residues on grain and protection of the environment. These concerns increasingly constrain the use of agricultural chemicals.

Increased cultivation can reduce the weeds present during harvest, thereby reducing the dockage and FM levels. Increasing cultivation, however, raises fuel and equipment costs. Further, more cultivation exposes the soil to increased erosion. Given the conservation requirements contained in the 1985 and 1990 farm legislation[6] and the role no-till and other conservation tillage practices have in meeting these requirements, this option is seen as less likely to occur than others discussed.

Harvesting Practices

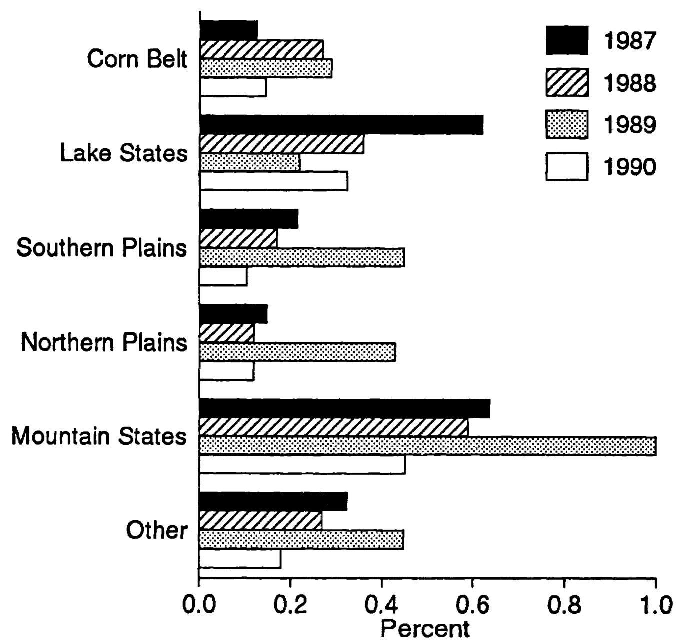
Changing harvesting practices can result in cleaner wheat, but changing harvesting practices can increase production costs. In addition, the potential reduction in nonwheat material varies by class of wheat and by year.

Spring wheat contains more dockage than winter wheat, partly because of the difference in harvesting practices. Spring wheat, produced in the Northern Great Plains, is harvested later and often windrowed prior to harvest. Windrowing permits quicker drying and harvesting, reduces risk of weather damage, interrupts some weed and seed development, and lowers harvesting costs. However, the use of a pickup header during harvest inevitably collects soil, weeds, and other nonmillable materials with the wheat. Winter wheat, produced in milder climates such as the Central and Southern Great Plains, generally dries naturally and is straight combined, resulting in less dockage and FM. FGIS inspection data for the 1986-90 wheat crops can be used to illustrate the relative dockage level for different wheat classes. The reported average dockage levels for hard red winter (HRW), soft red winter (SRW), and hard red spring (HRS) are 0.86, 0.85, and 0.94 percent, respectively. However, the dockage and FM vary from year to year (figs. 4 and 5).

Farmers can also reduce dockage and FM in wheat by altering harvesting practices. Careful adjustment of combines, attachment of a cleaner to the combine, and the use of straight combine harvesting can lower the amount of soil and weed seeds gathered with the wheat.

Adam and Anderson reported that proper adjustment of a combine has costs. They found that combine adjustments require a highly trained operator who would need to repeatedly make up to 13 different combine settings

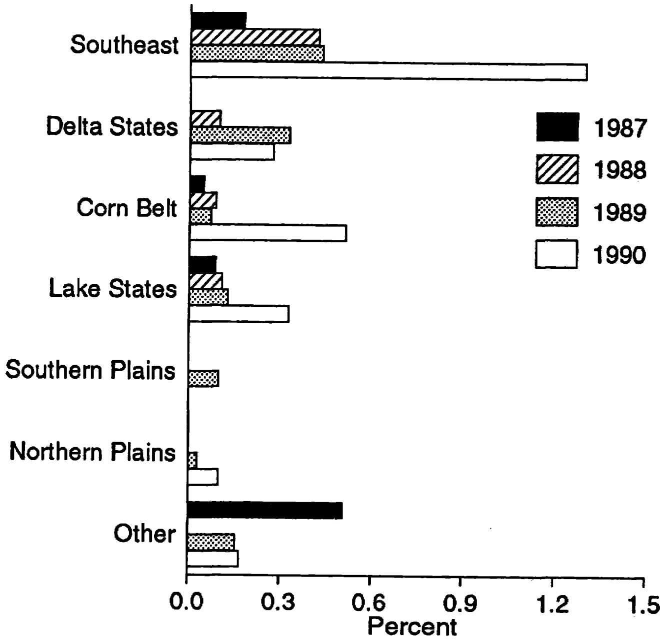
Figure 4
Foreign material in hard red winter wheat: Variations in yearly averages 1987-90



Data from the FGIS new crops survey.

[6]P.L. 99-198, Title XII of the Food Security Act of 1985, amended by P.L. 101-624, Title XIV of the FACTA of 1990, restricts agricultural practices for farmers receiving crop payments for program crops grown on highly erodible soils. In many cases, the title results in the adoption of reduced tillage cropping on wheat acres.

Figure 5
Foreign material in soft red winter wheat: Variations in yearly averages 1987-90



Data from the FGIS new crops survey.

during the harvest. Crop conditions can vary greatly within a single field requiring several readjustments each day. Time used in making combine adjustments extends the time to complete the harvest, increasing the harvest cost. For farmers at harvest, time is of the essence. It is imperative to quickly cut wheat because rain, wind, or hail can reduce yields, lower *test weight*, and increase moisture.

Adjusting the combine may also increase fuel and drying expenses. In addition, the adjustments often result in a tradeoff between the amount of dirt and weeds included in the harvest and wheat loss in the field. Increasing wheat loss imposes a significant cost on farmers, not only reducing yields but raising production costs due to the need to control volunteer wheat in the next crop year.

The latest generation of grain combines operate at high capacities and yet facilitate monitoring and adjustments for grain loss, damage, and threshing performance. Older combines have the same capability to produce clean grain, but require greater operator time and attention. Universal adoption by farmers of more modern equipment may take many years. Much of the U.S. wheat crop is harvested by custom harvesters. These operations are adopting the modern combines sooner than most farmers.

Onfarm Cleaning

Without explicit premiums or discounts related to dockage, the high fixed cost, the loss of grain in handling, and the minimal reduction in storage losses would appear to discourage many farmers from cleaning wheat. A recent survey of U.S. farmers by the University of Illinois found that wheat producers ranked avoiding discounts and improving storability as their major reasons for cleaning. But the survey indicated that only 24 percent of the farms possessed grain-cleaning equipment. A higher percentage of farmers in Minnesota, North Dakota, and South Dakota owned onfarm cleaners than the national average.

The survey indicates that only 38 percent of the farmers owning cleaners use their cleaners for cleaning wheat, implying that fewer than 10 percent of farmers clean any wheat. Farmers use their cleaners primarily for seed cleaning rather than cleaning grain for market. The observation that farmers have cleaners but do not use them for cleaning wheat for market suggests that farmers do not find the return sufficient to cover the operating costs of cleaning.

Country and Subterminal Elevators

Country and subterminal elevators act as intermediaries between farmers, other elevators, and end-users. The options available to country and subterminal elevators are a subset of those available to farmers and export elevators. Country and subterminal elevators can clean wheat, offer premiums for wheat with a low dockage and low FM content, or blend wheat to meet customer demand. The characteristic that distinguishes these elevators is that they each operate in a somewhat different market with different suppliers and customers to balance different sets of economic incentives. Each elevator considers the price incentives and other potential benefits, equipment available, cost of clean wheat from alternative sources, and the variable costs of cleaning in determining whether or not to clean wheat. These elevators select the least-cost means of supplying wheat, with the appropriate dockage and FM characteristics, to end-users and other elevators.

Domestic Flour Mills

Flour millers are extremely risk-averse toward nonwheat material and, therefore, clean all wheat before milling. Millers are able to remove dockage, FM, and shrunken and broken kernels much more efficiently than elevators. The cost of cleaning wheat at mills changes very little with dockage and FM levels, leaving little incentive to offer premiums for cleaner wheat (Millers National

Federation, 1991). Two-thirds of the domestic flour millers who answered the milling survey do not specify dockage limits in their purchasing contracts.

The absence of premiums for clean wheat does not imply that millers are completely indifferent to dockage and FM; they would always prefer to receive as little dockage as possible. The millers that specify maximum levels of dockage and FM tend to specify levels that are less stringent than those for export contracts. Furthermore, domestic millers are familiar with the characteristics, including cleanliness, of wheat from different producing regions, and can target their purchases accordingly.

Export Elevators

Export elevators meet the cleanliness specifications of importers, both by acquiring grain that meets importer specifications and by cleaning. Wheat is cleaned at the export elevator when deliveries from interior elevators do not meet the required specifications, or when market conditions make it unavoidable. Little data are available on the cost of cleaning at export elevators, but the information available suggests that the slowing of the high-speed loading, the generally urban environment, the longer distance to transport screenings to livestock operations, and higher land values at port locations all tend to make cleaning at export terminals more costly than at other locations.

Methodology

The economics of cleaner wheat might be viewed as simply comparing the costs and benefits associated with cleaner wheat. In one sense, this is correct. On the other hand, the costs and benefits of cleaner wheat require an estimation of how each sector in the wheat marketing system would change. Because these conditions cannot be observed, economic engineering analysis is required to determine the cost of cleaning wheat to levels not obtained by current practices. Further, this process requires assumptions concerning the policy changes that are adopted, the response of economic markets, and the value of the economic parameters.

The results presented in this report were obtained from three broad sources: previous studies, data collected from surveys (see box on onfarm and off-farm surveys), and economic engineering studies. Each of the surveys requested information concerning dockage and FM in the wheat received, current wheat cleaning capacity and

Onfarm and Off-farm Surveys

Commercial Elevator Survey

- Conducted by the National Grain and Feed Association (NGFA) in conjunction with the U.S. grain industry.
- Sent 6,237 survey questionnaires to elevators registered by the Agricultural Stabilization and Conservation Service (ASCS).
- Received 895 usable responses--14 percent of the total commercial elevators.

Onfarm Survey

- Conducted by the National Association of Wheat Growers (NAWG) and the University of Illinois.
- Sent 67,000 postcard questionnaires in *The Wheat Grower*, a NAWG magazine to 67,000 members.
- Received 1,171 responses, or 2 percent of the NAWG membership.
- Sent 310 (26 percent of the respondents) more detailed questionnaires to members owning cleaners.
- Received 170 of the detailed questionnaires or less than 1 percent of the NAWG membership.

Flour Mill Survey

- Conducted by the Millers National Federation (MNF).
- Sent 41 survey questionnaires to all company members.
- Received 18 responses dealing mostly with company operations--approximately 40 percent of the total U.S. flour milling capacity.

practices, cost of cleaning wheat, and discounts and premiums observed. More details are provided in appendix A.

Economic engineering studies from North Dakota State and Oklahoma State Universities are also used to estimate the benefits and costs of cleaning spring and winter wheats at commercial elevators under two possible scenarios: (1) the cleaning of all nonfeed wheat, and (2) the cleaning of all U.S. export wheat. These studies used the economic engineering approach to estimate the cost of providing this cleaner wheat and determine the least-cost means of providing cleaner U.S. wheat. The assumptions used are presented in table 2. The methods and procedures used by the engineering studies are provided in more detail in appendix A.

Cleaning all wheat exported is comparable with grain-handling policies adopted by Canada and Australia. It is a policy option consistent with the goal of matching our major competitors in terms of cleanliness in export markets. Cleaning all nonfeed wheat goes beyond any current proposal for U.S. wheat, but would imitate the Canadian and Australian wheat marketing systems.

The general approach used to examine the changes that take place in U.S. wheat markets is to hold the aggregate (world) market demand and supply constant. In essence, these results assume international wheat prices and trade are not affected by the change in U.S. wheat cleaning practices. A companion report, *The Role of Quality in Wheat Import Decisionmaking*, (Mercier, 1993) focuses on possible changes in world markets if the United States sells cleaner wheat.

Table 2--Parameters used in engineering studies

Parameters	Units	Oklahoma State University (winter wheat)	North Dakota State University (spring wheat)
Price of wheat	$/bu	3.00 [2.00-4.00]	2.24 country 3.36 export (126.50/ton)
Value of cleanings (f.o.b. local)	$/cwt	2.00 [0-4.00]	1.50 [1.00-2.00]
Operating labor wage	$/hr	6.00 [4.00-10.00]	7.71 country 35.00 export
Supervisory labor wage	$/hr	13.00	NA
Electric rate	$/kwh	.105 [0-.20]	.05
Hours of operation	Hrs/yr	1,000	700 [350-1,050]
Wheat loss	Percent	.75-1.1	.7 [.1-1.1]
Premium for cleaned wheat	$/bu	0 [0-.04]	NA
Transportation rate	$/bu	0.75 [0-2.00]	.30-1.00
Beginning dockage level	Percent	.85	3 [1.0-5.0]
Target level of dockage	Percent	.35 [0-.8]	.4 [.1-1.0]

[ ] = Range. f.o.b. = free on board. NA = Not applicable.

Determinants of Costs and Benefits of Cleaning Wheat

Producers, handlers, and flour millers decide to clean wheat by weighing the benefits of reduced dockage and FM against the costs of cleaning the wheat. The main factors affecting the costs of cleaning are the capacity and efficiency of grain cleaners, the beginning and ending dockage levels, and the loss of revenue from selling sound wheat with unmillable material as screenings (wheat loss). Benefits, excluding trade effects, include reduced transportation, handling, and storage costs. The existence of premiums for clean wheat, or discounts for wheat with high levels of nonwheat material, is a pivotal determinant of the amount of cleaning in the United States.

Determinants of Costs of Cleaning Wheat

Although the determinants of costs are separated into distinct categories, they are interrelated. For example, the capacity and efficiency of cleaning equipment affects both fixed and variable costs. Increasing cleaning capacity increases capital costs and the total fixed cost; however, if this capacity is used efficiently, average variable costs can be reduced. Also, wheat loss, the largest cost incurred from cleaning wheat, increases as the difference between the beginning and ending dockage level widens.

Fixed Costs: Capacity and Efficiency of Cleaners

Ownership of wheat cleaning equipment incurs fixed costs (interest, depreciation, and property taxes) whether the capacity is used or not (see box on commercial wheat cleaning capacity). Efficient use, as well as capacity of cleaning equipment, is an important determinant of costs. The average fixed and variable cleaning costs decrease as a cleaner's actual rate of use approaches the manufacturer's rated capacity. Because an annual volume approaching 1 million bushels of wheat is required to minimize variable costs, large commercial elevators are most likely to have the lowest average variable costs. Thus, many low-capacity cleaners, due to the higher costs of cleaning, are not suited for cleaning wheat for market, but instead are primarily used for specialized situations, such as cleaning seed wheat.

Wheat (Screening) Loss

Wheat or screening loss is the largest cost associated with cleaning wheat (figs. 6 and 7). Wheat loss refers to the loss of revenue from the removal of nonmillable material, such as shrunken and broken kernels, FM, and

Figure 6
Cost of operating a screen cleaner

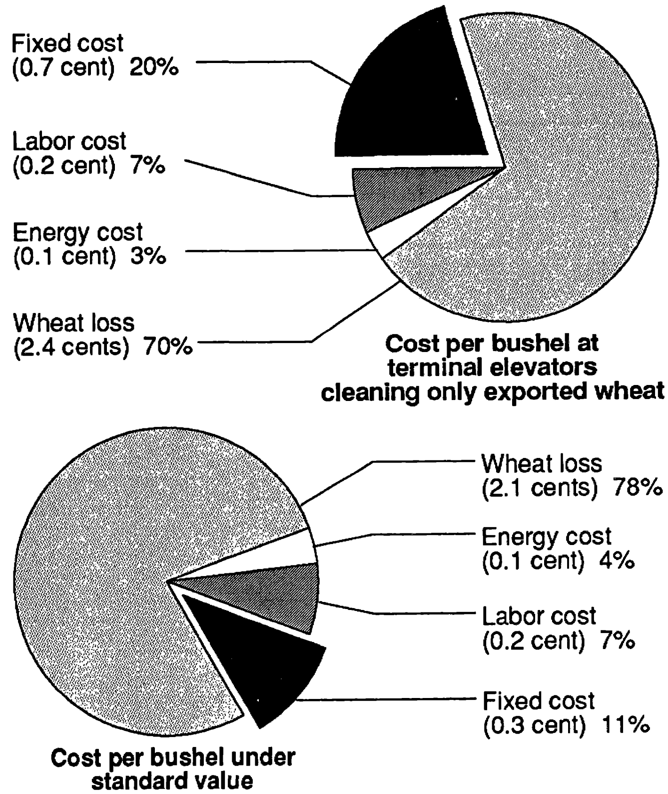
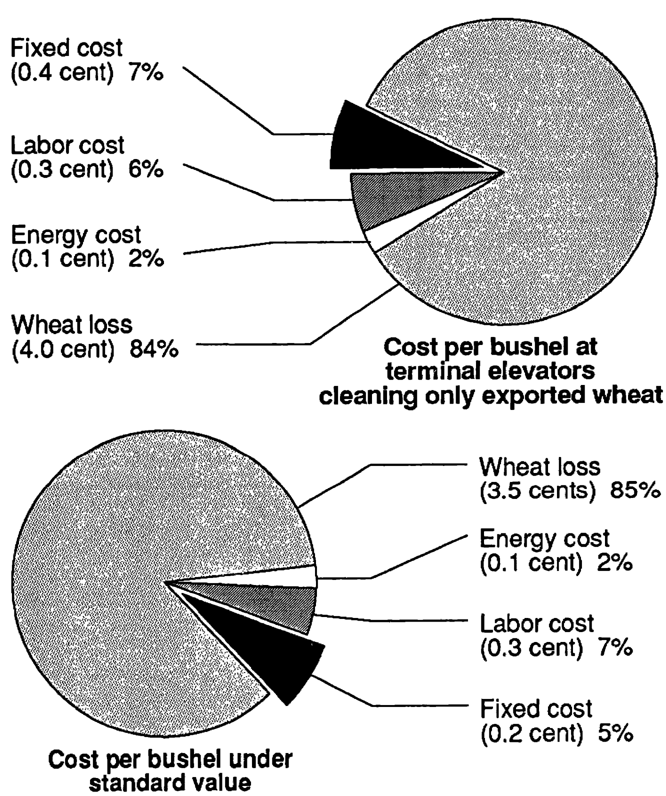


Figure 7
Cost of operating an aspirator cleaner



Note: May not sum to 100 percent due to rounding.

Commercial Wheat Cleaning Capacity

It is estimated that cleaning capacity at U.S. elevators handling wheat is 4.2 million bushels per hour (BPH). Of this, 2.9 million BPH is available at elevators cleaning winter wheat and 1.9 million BPH is available for elevators cleaning spring wheat (appendices B and C).

Although spring wheat accounts for only 30 percent of U.S. wheat production, elevators handling spring wheat have 45 percent of the cleaning capacity. The major reason for this is that spring wheat has a higher dockage level than winter wheat and requires more cleaning. In 1990, 97 percent of the elevators in North and South Dakota cleaned spring wheat (NGFA, 1991). Half of the elevators in South Dakota cleaned all the wheat they handled, while in North Dakota, half of the elevators cleaned at least 75 percent of the wheat handled. In contrast, only 33 percent of elevators in Texas and Oklahoma, two major winter wheat-producing States, cleaned winter wheat. Elevators in the white wheat areas of the Pacific Northwest cleaned little wheat.

There are many types of cleaners used in cleaning wheat. All cleaners separate dockage using methods that take advantage of differences between wheat and dockage characteristics. The three common types are *screen*, *aspirator*, and *disc-cylinder cleaners*. Each of these cleaners is best suited for removing certain materials. A survey of grain-cleaning practices at commercial elevators showed that screen cleaners were most common (NGFA, 1991).

If incentives to supply cleaner wheat change, the type and capacity of cleaning equipment will also change. This holds because the average age of the grain cleaners in the United States is 20 years (NGFA, 1991), while the average life expectancy of the cleaners is between 20 and 40 years. As the older cleaners are retired, more efficient cleaners would likely replace them.

sound wheat from the wheat during the cleaning process.[7] Without cleaning, farmers, elevators, and exporters sell this material on a weight basis as wheat. With cleaning, this nonmillable material can be sold only to the livestock industry as screenings (a byproduct feed) at a much lower price. Thus, wheat loss during cleaning imposes a cost to the elevator. For this reason, cleaning becomes more economical when wheat prices are low, resulting in a lower value of the wheat loss.

Wheat loss tends to increase as the intensity of cleaning increases. Wheat kernels are not homogeneous in size or density. The longer wheat is cleaned (as the openings in the screen increase to remove more dockage), the greater the probability that undersized kernels will also be removed. Wheat handlers are faced with a tradeoff between a higher wheat loss and slower throughput associated with a lower ending dockage level, and a lower wheat loss and higher throughput associated with a higher ending dockage level. Wheat loss can be minimized by reducing the intensity of cleaning or rescreening to reclaim material (including wheat) which otherwise would be removed. Neither strategy is fully satisfactory because the first results in higher final dockage levels and rescreening has higher operating costs due to an additional handling.

Beginning and Ending Dockage Levels

As the difference between the beginning and ending dockage level increases, the cleaning process slows, causing total, operating, and fixed costs to increase. The variable costs increase because (1) the cleaner must operate longer to clean the same amount of wheat, and (2) wheat loss increases. The fixed cost per bushel rises because less wheat can be cleaned per hour of operation.

The economics of cleaning at the elevator will vary between crop years because weather influences the amount of dockage and FM. Country elevators generally do not clean incoming wheat that has less than 1.9-percent dockage at harvest and 1.5-percent post-harvest (Scherping and others, 1992). When elevators do clean, they seldom go below 0.8-percent dockage unless the wheat is contracted for less. In most years, 70-80 percent of the U.S. wheat crop sold to country elevators already contains less than 1-percent dockage.

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[7]To the extent that dockage is not deducted from the total weight, then the weight of dockage removed is also included as wheat loss. This can occur if wheat is purchased on a gross weight basis, or if wheat is cleaned to a point where the amount of dockage is below the level where it becomes nondeductible.

Energy and Labor Costs

Substantial changes in either energy or labor prices will not have a strong impact on the economic feasibility of cleaning wheat (Adam and Anderson, 1992). Energy and labor costs vary across the country, but comprise a small portion of cleaning costs in all observed situations (figs. 6 and 7).

Determinants of the Benefits of Cleaning Wheat

Screenings sales and transportation savings are the two most important domestic benefits from cleaning wheat. In addition, wheat cleaning can result in other benefits, such as lower costs for drying, *aeration*, storage, and insect control; smaller discounts for test weight, FM, and shrunken and broken kernels; insurance savings; and greater lot uniformity.

Cleaning could potentially reduce safety and health-related hazards by reducing dust levels and lowering dust control costs. This could result in fewer problems with the compliance of quarantine requirements for weed seeds in certain export markets. However, this study does not address these potential benefits.

Revenue from Screenings

Although wheat screenings are obviously less valuable than wheat, revenue from the sale of wheat screenings can partially offset the cost of wheat loss from cleaning wheat. Because screenings are used as a livestock feed, the market price of screenings is primarily determined by the price of competing feeds and its feed value relative to those feeds. In the period between 1990 and 1991, the price commercial elevators received for winter wheat screenings ranged from $9 to $80 per ton, with an average of $40 per ton (NGFA, 1991).[8]

Flour millers use a somewhat different market. Nearly all millers combine screenings with wheat millfeed (a milling byproduct), which is sold as middlings for feed. A market for milling byproducts is already well-developed in the United States. In 1990, the average price of wheat middlings was $67 per ton.

Although an increase in cleaning could increase the supply of screenings and depress the price in some local markets, screenings are such a small part of the livestock feed market that there would not be a nationwide price effect. The value of screenings varies greatly by the location of grain cleaner. The net value of screenings (less handling and transportation costs) declines rapidly as the distance to the buyer increases. If grain cleaning occurs in urban areas far from livestock operations, the value of screenings can become negative due to the need for disposal. Thus, the supply of cleaner wheat declines when the price of screenings is low or in areas where there is no market for screenings, all other things held equal.

Transportation Savings

Cleaner wheat can reduce transportation costs by reducing the dockage and FM transported with wheat. Other things being equal, the higher the transportation rates and the longer the distance wheat is shipped, the greater the potential savings from cleaner wheat.

An interesting issue is who is able to capture the potential transportation savings. If the wheat is purchased f.o.b., the standard practice for exported U.S. wheat, then the buyer pays the transportation costs and stands to benefit from cleaner wheat. On the other hand, U.S. flour mills generally purchase wheat for delivery to the mill gate, passing the concern for transportation costs back to the elevator or handler. In this case, the elevator stands to gain any transportation savings from cleaner wheat.

Country elevators likely face the highest total transportation costs because they have the longest shipping distances and, in some cases, may be unable to get volume discounts. This suggests that wheat moving from country elevators to export points has a greater potential to accumulate transportation savings. Conversely, wheat moving to domestic terminal markets has less to gain from cleaning. The major spring wheat-producing States generally face higher transportation expenses, around $20 per ton in the prevailing market. These prices, combined with high dockage levels at harvest, help to explain the high concentration of cleaners in the upper Midwest. However, Johnson and others (1992) found that under current distribution patterns, North Dakota transportation rates would need to approach $30 per ton to induce additional cleaning to a 0.35-percent dockage level.

Storage Benefits and Savings from Insect Management

Cleaning wheat before storage may reduce energy, chemical, and insect control costs. By removing small particles that restrict air movement in stored wheat, cleaning reduces aeration time, hastens cooling of the grain mass, aids dissemination of fumigants, and limits conditions that promote insect populations and mold growth.

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[8]The price for wheat screenings was the free on board (f.o.b.) price, which reflects the demand for screenings net of the transportation costs to the purchaser.

The energy savings from cleaner wheat depend on the depth and size of the silo. The larger the silo the greater the savings. Adam and Anderson (1992) estimated that the savings range from 0.022 cents per bushel for 50-foot silos to 0.14 cents per bushel for 120-foot silos.

Cleaner wheat offers limited potential savings from lower *fumigation* costs. The savings depend on the amount of grain fumigated and the duration of the storage. The potential savings from reducing dockage in stored wheat are limited because not all wheat is stored long enough to warrant fumigation, much of the storage capacity for spring wheat is in a low-risk zone for storage deterioration, alternatives for controlling storage losses may be more cost-effective than cleaning, and grain-handling practices at commercial elevators seek to eliminate growing conditions conducive for rapid insect and mold growth (see box on potential savings from reducing insect control costs). Cleaning winter wheat would generate 0.062 to 0.41 cents per bushel in savings from reduced insect losses and lower fumigation costs (Adam and Anderson, 1992).

Insurance Savings for Reduced Explosion Hazard

The effects of grain cleaning on the safety environment at elevators are difficult to measure. It has been postulated that cleaning wheat may reduce insurance premiums by reducing the risk of explosion or other damage or injury to employees. However, Adam and Anderson were unable to find any insurance company that offered a reduction in rates for grain storage facilities that cleaned grain before storage. In fact, to cover potential losses for the grain cleaner itself, total insurance costs would be slightly higher than without a cleaner. This cost would be incurred regardless of the usage.

Reduction of Discounts

Cleaning wheat could reduce discounts by improving test weight, reducing FM, and lowering the amount of shrunken and broken kernels. Discounts for excess FM and shrunken and broken kernels are applied to approximately 10 percent of the wheat crop. Factoring the 230 million bushels affected by these discounts would produce a maximum aggregate benefit available from cleaning of $2.4 million each year (see box on cleaning and test weight discounts).

Premiums for Cleaner Wheat

Engineering simulations indicate that offering premiums for low-dockage wheat would greatly increase the profitability of cleaning (Adam and Anderson, 1992, p. 112). However, surveys conducted by Oklahoma State University, NGFA, and MNF found little evidence of premiums being offered for low-dockage wheat. Thus, commercial elevators apparently do not face effective incentives to produce or acquire cleaner wheat.

Potential Savings from Reducing Insect Control Costs

Alternative measures for controlling storage losses include using grain spreaders and grain *protectants*, *turning* grain, rotating stocks, and cleaning the bins and equipment when emptied or not in use.

Among the factors limiting the savings is the relationship between dockage and population growth rates of insects and mold. Insects and mold population growth rates seldom become critical until dockage levels reach 5-10 percent. Few bins of any wheat class ever have dockage higher than 5 percent. The provision in the 1990 Food, Agriculture, Conservation, and Trade Act requiring USDA to establish minimum cleanliness standards for grain stored by the CCC further reduces the likelihood of high dockage levels in stored wheat in the future.

Grain boring insects such as weevils require no fine materials to develop if they are present and grain temperatures are warm enough. Insect activity and mold growth generally require grain temperatures in excess of 60° F. The temperature of appropriately dry spring wheat stocks rarely, if ever, exceeds 60° F during the post-harvest winter months. Winter wheat is harvested earlier and is subjected to warmer temperatures.

Improvement in Uniformity

Uniformity could enhance the competitiveness of U.S. wheat in markets where variability is a concern. This uniformity is important to flour millers because it reduces their adjustments in the cleaning process and permits a more precise accounting of milling costs. Extensive

Cleaning and Test Weight Discounts

Because test weight is calculated on a dockage-free sample, no increase in test weight is gained by removing dockage. Thus, cleaning with aspirators or screen cleaners would not do much to improve test weight (fig. 8). Although some shrunken and broken kernels would also be removed, causing a marginal gain in test weight, reducing FM requires a disc-cylinder type cleaner. This explains why the discount for FM is higher than the discount for an equivalent amount of an easier-to-remove impurity. The reduction in shrunken and brokens and FM would have little effect on test weight and the subsequent discount. About 70 percent of U.S. domestic wheat inspections have test weight exceeding 60 pounds (the U.S. No. 1 limit for all classes excluding HRS), which would have no discount. The remaining wheat is clustered above 58 pounds, which would have discounts generally less than 2 cents.

cleaning throughout the wheat marketing system would reduce the variability of dockage levels between and within shipments. Fewer sublots blended into a shipment would have a dockage content much higher than the average. The risk of having shipments that exceed the contracted or maximum dockage allowance would also be less. Cleaning would not only improve uniformity at loading, but also uniformity at destination (affected by particle segregation in transit).

Costs and Benefits of Cleaner Wheat

The costs of cleaning either all nonfeed wheat or all exported wheat exceed the domestic benefits. Thus, an overall reduction in dockage and FM could benefit the wheat industry only if cleaner U.S. wheat induces sufficient trade benefits to overcome the costs (see appendices B and C for greater detail). This section summarizes the benefits and costs of additional cleaning. These results are derived from surveys and engineering studies.

Wheat Cleanliness in the United States

Average dockage and FM content of U.S. wheat arriving at flour mills and export terminals were lower than at the farm or country elevators, indicating that the marketing system provides, identifies, and directs cleaner wheat to flour mills and export markets (figs. 9 and 10). For example, survey data indicate dockage in HRW wheat had an average of 1.2 percent (with a standard error of 0.08) at harvest, but 0.5 percent (with a standard error of 0.09) at the export terminal. FM also declined from 0.9 percent (with a standard error of 0.08) at harvest to 0.4 percent (with a standard error of 0.17) at the export terminal (appendix B).

The average dockage reported by participating export elevators is significantly less than the average dockage in export shipments as determined by FGIS shipboard inspections. Also, the average amount of FM reported in the survey is somewhat higher than is indicated by FGIS shipboard inspections. These results reflect that the data supplied from the commercial elevator survey are the result of an overall impression and are not as accurate as the FGIS shipboard inspection data. These results also suggest that the number of export elevators in the sample do not adequately represent the full population of export elevators. However, when the average dockage (0.8 percent) and FM (0.3 percent) is estimated using the FGIS data, the observation that the amount of dockage and FM declines from the farm to the export elevator still holds. This finding is contrary to the frequently stated allegation that U.S. grain becomes less clean as it moves through the grain marketing system.

Wheat delivered to export markets is cleaner than wheat delivered to domestic flour mills. Dockage in HRW wheat delivered to flour mills averaged 0.1 to 0.4 percent higher than that received by export terminals. Given that flour mills clean all wheat and importers of U.S. wheat have substantial transportation costs, this result suggests that the marketing system in aggregate is effective in identifying higher dockage wheat and moving it to domestic end-users who can handle it at the lowest cost.

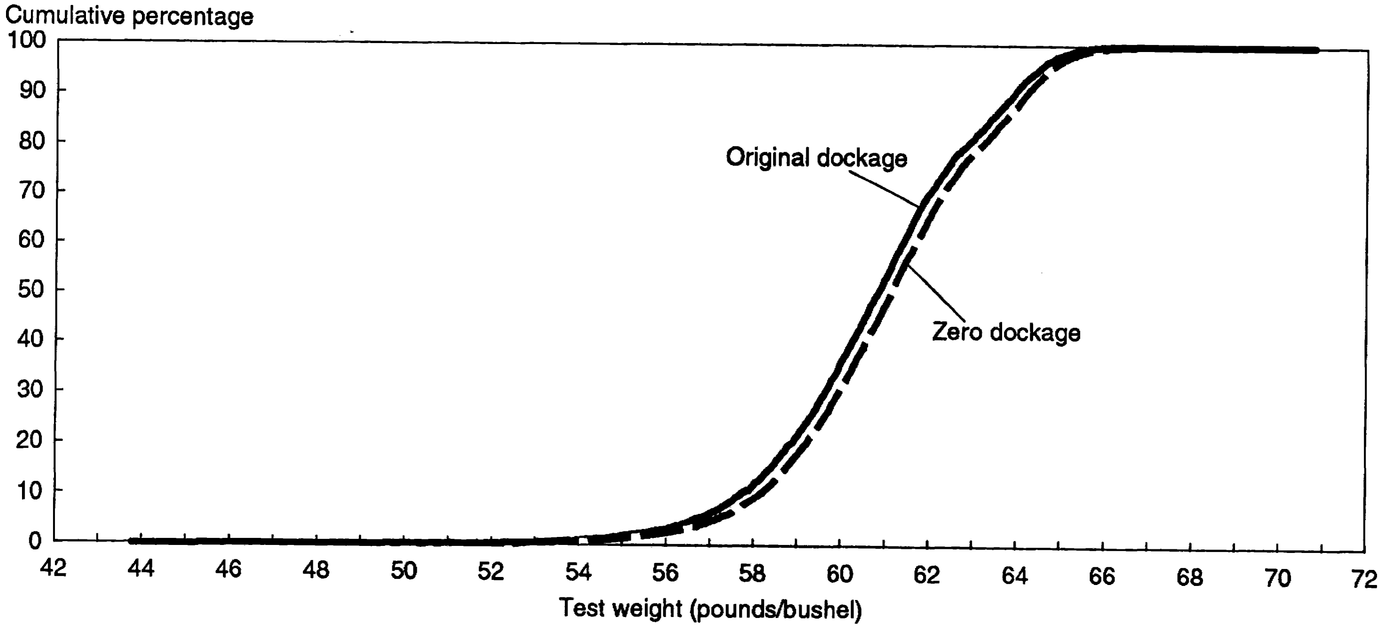
Domestic Flour Millers

U.S. flour millers clean all wheat received before milling, integrating the cleaning operation into the milling processes. This practice results in an average variable cleaning cost of 4.4 cents per bushel (MNF, 1991), and limits the potential benefits from additional cleaning at other points in the marketing and distribution chain. Because millers clean all wheat received to a minimal level of dockage and FM, prior cleaning by elevators would be superfluous.

Export Elevators

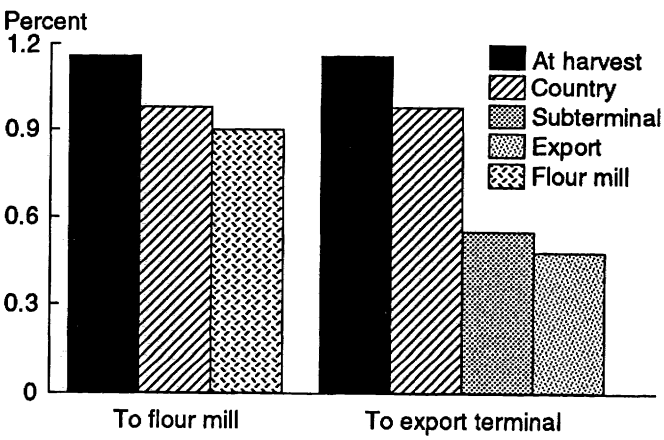
If additional cleaning were performed at export elevators, costs would exceed the benefits, resulting in a net cost. The aggregate net cost (that is, cost of cleaning minus domestic benefits) of cleaning all export wheat is

Figure 8
The effect of removing dockage on the test weight of wheat



Based on 10,587 random samples of 1988 domestic wheat inspections.
Source: USDA, FGIS, 1988.

Figure 9
Dockage in hard red winter wheat: Through the marketing channel



Source: Onfarm, commercial elevator, and flour mill surveys (NAWG, NGFA, MNF).

estimated to be between $31 and $36 million (table 3). The aggregate net costs increase as the quantity cleaned increases.

There are three reasons that the net cost of cleaning at export elevators is greater than the net cost of cleaning at subterminal elevators.

(1) Higher fixed costs--due to the high property values at ports, and the need to either match cleaning and load-out capacity, or acquire additional storage capacity.

(2) Reduced market for screenings--because there are fewer nearby livestock operations. Also, higher transportation and handling costs would reduce the net price received for screenings.

(3) Higher value of wheat lost during cleaning--because the price of wheat at the port includes additional transportation and handling charges.

Figure 10
Foreign material in hard red winter wheat: Through the marketing channel

Source: Onfarm, commercial elevator, and flour mill surveys (NAWG, NGFA, MNF).

White wheat is the exception to the finding that wheat cleaning costs are higher at export terminals. The reasons for this are: white wheat tends to be cleaner at harvest, only small quantities of white wheat are now cleaned, country elevators have little wheat cleaning equipment, subterminal elevators are less common in the white wheat region, white wheat is grown close to the export elevators so potential transportation savings are low, and the region is a feed deficit area so a screenings market is available to export elevators.

Subterminal Elevators

Cleaning all winter wheat for export at subterminal elevators was estimated to result in a net cost of $12 million, while the net cost of cleaning all nonfeed winter wheat was $17 million (table 3). Although subterminal elevators were the most cost-effective site examined for cleaning winter wheat, cleaning still resulted in a net cost for the options examined. Cleaning spring wheat at subterminal elevators was not examined because in the spring wheat region country elevators ship most of the wheat directly to either flour mills or export elevators.

Both the aggregate costs and aggregate benefits of cleaning winter wheat at subterminal elevators increase as the volume cleaned is increased. The cost of cleaning all U.S. export winter wheat was estimated to be $27 million. Increasing the amount cleaned to include all nonfeed winter wheat was estimated to have an aggregate cost of $41 million. Although the benefits from cleaning all nonfeed winter wheat ($24 million) exceeded those obtained from cleaning exported winter wheat ($16 million), the increased benefits were less than the increased cost. Because the additional costs from cleaning all nonfeed wheat were greater than the increased benefits, the total net cost increased (table 3).

The total net cost of cleaning increased as the amount of wheat cleaned increased. This increase occurred even though the average cost per bushel cleaned decreased as the volume cleaned increased. This result indicates that while there may be some efficiencies to be gained from increased volume, without additional benefits, these economies of scale are insufficient to make indiscriminate cleaning cost-effective. Using the assumptions from the engineering studies, cleaning costs at subterminal elevators ranged from 3.6 to 3.8 cents per bushel (table 4). Fixed costs accounted for less than 20 percent of the total cost.

Country Elevators

The costs of cleaning additional wheat at country elevators also exceeded the benefits (tables 3 and 4). The aggregate net cost of cleaning all export wheat at country elevators was $38 million. Increasing the volume to include all nonfeed wheat raises the total net cost to $54 million.

Both the aggregate costs and aggregate benefits of cleaning wheat at country elevators are affected by the volume cleaned. The annual cost of cleaning all nonfeed wheat was estimated to be $91 million. If the amount cleaned were reduced and only export wheat were cleaned, the aggregate cost would be $62 million, a reduction of $29 million (table 3). The aggregate benefit of cleaning all nonfeed wheat is estimated to be $38 million. This is $13 million greater than the aggregate benefit from cleaning U.S. wheat exports ($24 million). As with subterminal elevators, the additional costs incurred by more cleaning were greater than the additional benefits generated, increasing the net cost.

The national average cost of cleaning wheat at country elevators ranges from 1.9 cents per bushel to 6.7 cents per bushel, depending on the quantity to be cleaned (table 4). As more wheat was cleaned, the per bushel cost of cleaning decreased. Much of the decrease was due to the distribution of fixed costs over a larger volume, but there was some savings due to operating efficiencies. Because cleaning wheat has a net cost under all circumstances, the aggregate net cost increased as volume increased.

The country elevators have a higher net cost for cleaning winter wheat than subterminal elevators for two reasons.

Table 3--Aggregate costs and benefits of cleaning additional wheat

Type of wheat	All export wheat: Country elevator[1]	All export wheat: Subterminal	All export wheat: Export elevator	All nonfeed wheat: Country elevator	All nonfeed wheat: Subterminal	Least net-cost option
			Million dollars[2]			
Costs of additional cleaning:						
White	8	NA	8	11	NA	8
HRS and durum	6	NA	12	12	NA	6
Winter	48	27	NA	68	41	27
Total	62	NA	NA	91	NA	41
Benefits of additional cleaning:						
White	2	NA	2[3]	3	NA	2
HRS and durum	1	NA	1[3]	2	NA	1
Winter	22	16	NA	33	24	16
Total	24	NA	NA	38	NA	19
Net costs of additional cleaning:						
White	6	NA	6[3]	9	NA	6
HRS and durum	5	NA	11[3]	10	NA	5
Winter	27	12	14-19	34	17	12
Total	38	NA	31-36	54	NA	23

NA = Not available. [1]Numbers do not completely agree due to rounding. [2]Cleaning at all other types of elevators is held at current levels. [3]To provide some of shipment at dock, but not all. Source: Adam and Anderson, 1992; Johnson and others, 1992; Johnson and Wilson, 1992; Scherping, Cobia, Johnson, and Wilson, 1992; Wilson, Scherping, and Johnson, 1992.

Table 4--Costs and benefits of cleaning wheat

Type of wheat	All export wheat: Country elevator	All export wheat: Subterminal	All export wheat: Export elevator	All nonfeed wheat: Country elevator	All nonfeed wheat: Subterminal	Least net-cost option
			Cents/bushel[1]			
Costs of additional cleaning:						
White	4.5	NA	3.7	4.5	NA	3.7
HRS and durum	1.9	NA	3.7	1.9	NA	1.9
Winter	6.7	3.8	NA	5.9	3.6	3.8
Benefits of additional cleaning:						
White	0.8	NA	0.2	.8	NA	.8
HRS and durum	.3	NA	.2	.3	NA	.3
Winter	3.0	2.2	NA	2.9	2.1	2.2
Net costs of additional cleaning:						
White	3.7	NA	2.9	3.7	NA	2.9
HRS and durum	1.6	NA	2.6	1.6	NA	1.6
Winter	3.7	1.6	1.9-2.6	3.0	1.5	1.6

NA=Not applicable. [1]Cleaning at all other types of elevators is held at current levels. Sources: Adam and Anderson, 1992; Johnson and Wilson, 1992; Scherping, Cobia, Johnson, and Wilson 1992; Wilson, Scherping, and Johnson, 1992.

First, more country elevators would need to acquire cleaning equipment than subterminal elevators. This raises total capital expenditures and fixed costs. Second, the smaller volume of winter wheat that is handled by many country elevators precludes the use of larger cleaners that are economically efficient when used by subterminal elevators. Also, the smaller volume associated with country elevators does not capture other efficiencies associated with cleaning larger amounts of wheat. Thus, the lower volume raises variable costs. Roughly two-thirds of the total cost of cleaning at country elevators are variable costs, primarily wheat loss. The other third is the cost of purchasing and financing the grain-cleaning equipment.

The difference between the cost of cleaning winter wheat at country elevators and subterminal elevators is much larger than the difference between cleaning at export elevators and subterminal elevators. This suggests that the economies of size have been largely captured by the time the wheat is cleaned at the subterminal level.

On the other hand, cleaning spring wheat at country elevators is more efficient than cleaning at either subterminal or export elevators. The reasons for this are due to the nature of the spring wheat marketing system, as follows:

(1) Country elevators handling spring wheat already have the necessary cleaning capacity and clean most wheat as a standard practice. Cleaning to a 0.4-percent dockage level would intensify current practices, but not require much additional machinery.

(2) Subterminal elevators are less common in the spring wheat region, so cleaning spring wheat at subterminal elevators would involve additional shipping and handling and therefore be infeasible.

(3) Indiscriminate cleaning of spring wheat at export elevators would generally require the installation of additional legs, conveyers, and storage facilities as well as cleaners. The added costs of this investment combined with higher labor costs and wheat losses, lower screenings prices, and additional (but indeterminate) costs associated with retrofitting would result in higher operating costs for export elevators.

Benefits from cleaning wheat at country elevators are higher than benefits at subterminal elevators, because all potential savings from reduced transportation, aeration, and fumigation expenses are captured. When cleaning takes place further along the wheat marketing system, some of the potential transportation and storage savings are lost. The total benefit from cleaning wheat would range from 0.8 to 3.0 cents per bushel (table 4). In aggregate, the benefits would increase as more wheat is cleaned.

Cleaner Wheat From Farms

Farms do not appear to be a feasible site for widespread additional cleaning. Based on an economic-engineering simulation, net returns for cleaning on the farm range from -18 to +5 cents per bushel (appendix D). Positive net returns are found only in exceptional circumstances. The amount of the net return varies, depending on the original dockage level, the number of bushels cleaned, and the value of screenings. Based on conditions that most farmers would face, the average net return for cleaning would be approximately -10 cents per bushel. This simulation, supported by the observation that farmers who own cleaners use them primarily for seed, strongly suggests that additional cleaning on farms would not yield net benefits.

Farmers also have the ability to provide cleaner wheat by altering production and harvesting practices. Although a detailed analysis of the cost of producing cleaner wheat by changing farm practices was not undertaken by this study, the costs to farmers from altering farm practices is likely to outweigh any potential gains they might obtain.

Optimal Point for Cleaning Wheat

The lowest net cost presented in table 3 indicates winter wheat cleaning at subterminal elevators, spring wheat cleaning at country elevators, and white wheat cleaning at export terminals. This solution provides the best available estimate for the cost of matching the Canadian and Australian strategy. However, given the previous discussion, the methods used to generate our cost estimates are inadequate to capture the unique circumstances of each elevator. Not all country elevators are smaller than subterminal elevators, some country elevators in the winter wheat region would likely be able to clean as efficiently as the subterminal elevators. In addition, there may be some terminal elevators that have the capacity to clean their throughput efficiently. Any strategy selected to generate cleaner U.S. wheat should be flexible enough to take this diversity into account.

Regional Impacts of Cleaner Wheat

The effect of a change in wheat cleaning practices would vary, depending on the new level of cleaning. If subterminal elevators cleaned exported wheat to 0.4-percent dockage, the net cost of cleaning spring wheat would be higher than the net cost of cleaning winter wheat (table 4). Thus, North Dakota, South Dakota, Minnesota, and Montana, the States where most HRS is grown, would be expected to bear a disproportionate share of wheat cleaning costs. On the other hand, if the marketing system were allowed to find the least cost location to clean wheat, the white wheat region would bear a higher cost than other regions. Also, the cost of cleaning wheat in the major SRW States is higher than the cost of cleaning wheat in the major HRW-producing States (Adam and Anderson, 1992, appendix B).

Not all importers will change their purchases in response to cleaner U.S. wheat. The impact on port areas will depend on the response of the countries they supply. Ports supplying countries that change their purchases of U.S. wheat would differ from ports that did not supply those markets. For instance, Korea is chiefly supplied by Pacific Northwest ports. If Korea were the only country that responded to cleaner U.S. wheat, the Gulf, Atlantic, Great Lakes, or St. Lawrence Seaway ports would not benefit from the increased trade, even though they incurred the same additional cleaning costs. Just as the benefits from increased trade to Korea would be passed back to the producers supplying the Pacific Northwest ports, the higher costs incurred at the other ports would inevitably work their way back to the HRS, HRW, and SRW wheat production areas that supply those other ports and other foreign markets.

Effect of International Markets on Net Costs

The lower dockage and FM in U.S. wheat can result in a change in the quantity of U.S. wheat demanded, the price received for U.S. wheat, or no change in demand. The results presented here assume no change in international demand for U.S. wheat. If no change occurs on international wheat markets, then the results presented above will hold. On the other hand, if the demand for U.S. wheat shifts so that the price received for wheat increases, benefits from cleaning increase, and then the net cost presented here will be an overestimate (table 4). If cleaning wheat results in shifting demand in a manner which increases U.S. wheat exports, but the price does not change, then the total costs will increase. In this case, the net cost presented will be an underestimate.

Implications of Cleaner U.S. Wheat

The costs of cleaning wheat exceed the domestic benefits, resulting in a net cost that must be borne by the industry. The wheat industry would likely respond to a change in cleanliness requirements by adopting the most efficient means to clean wheat. This suggests that approximately $23 million in net costs must be distributed between farmers, millers, elevator operators, and importers of U.S. wheat. It is difficult to determine which sector within the industry will bear this cost. However, flour millers will likely share a smaller burden than other sectors of the industry because they are risk averse, have the equipment in place, and will clean all wheat milled no matter what level of dockage it contains. They will bear a portion of the cost because, as the market now operates, flour millers and export elevators bid on the same wheat supplies with no price differential between the bidders. However, if limits are imposed on dockage levels for export, separate marketing channels may develop for export versus domestic destinations. This would reduce the flexibility of the wheat marketing system.

The net costs of cleaning wheat are a function of the point of cleaning and quantity of wheat to be cleaned. The location of the cleaning operation is the more important factor because grain cleaning exhibits economies of scale. Net domestic costs from cleaning winter wheat are minimized when the cleaners are located at subterminal elevators rather than country or export elevators. The lower net costs stem from the reduced capital requirements and operating costs at subterminal elevators, which more than offsets the marginally lower benefits from transportation savings. For spring wheat lower net domestic costs occur when cleaning takes place at country elevators because these elevators already clean wheat, have sufficient cleaning capacity, and subterminal elevators are less common in the spring wheat region.

The net domestic costs per bushel cleaned exceeded the benefits. This holds under all scenarios, although the per unit costs declined as the volume cleaned increased. Thus, the more wheat cleaned, the greater the total net cost. Because a larger volume is cleaned, cleaning all nonfeed winter wheat results in a higher aggregate net loss than cleaning only the winter wheat exported. Most of the higher net cost results from larger operating costs, although some additional capital expenditures are required.

Glossary

Aeration--The passage of air over or through grain to control the adverse effects of excessive moisture, temperature, and humidity. This is usually done by moving air with fans or through ducts.

Aspirator--A device that draws a column of high-velocity air across a flowing grain stream to separate low-density materials (foreign material, chaff, insects) from grain.

The air pressure is based on the weight of the grain. An aspirator can operate at a higher throughput capacity than screen cleaners but may result in a higher wheat loss. Aspirators are generally used to remove low-density materials, such as chaff and insects.

Blending--The systematic combining of two or more lots or kinds of grains to obtain a uniform mixture of a desired specification.

Carter dockage tester--A device approved by FGIS that uses a series of sieves to test the quantity of dockage in a sample of grain.

Certified seed--Seed that has been certified by the seller to have a minimal level of weed seeds.

Cleanliness--The absence of nongrain materials in wheat.

Crop rotations--The sequence of crops planted on a field. Farmers plant crops in rotations as farm management practice to reduce costs and increase production. Different crop sequences can alter the soil fertility, the susceptibility of the crop to insects and disease, and likelihood of soil erosion.

Disc-cylinder cleaner--Removes dockage on the basis of particle shape and length. Grain passes through the middle of a horizontal revolving cylinder, which has small indentations in the metal. Smaller materials fall into the indentations and is lifted as the cylinder revolves. As the material approaches the top of the cylinder, the material falls. Depending on the length of the material, it falls either into the dockage compartment or the grains compartment of the cleaner. Disc-cylinder cleaners are generally the most effective means to attain a low dockage level. However, their throughput capacity is generally less than other types of cleaners.

Discount--Reductions from the base price offered for grain. Discounts are generally calculated for factors that lower the value of the grain, and may be expressed as percentages of the price or as fixed cents per bushel. Discounts serve as a disincentive for selling grain below the quality of the base market grade.

Dockage--All matter other than wheat (such as chaff, stems, stones, etc.) that can be removed by the Carter dockage tester. It also may contain underdeveloped, shriveled, and small pieces of wheat kernels removed with the nonwheat material that cannot be recovered by proper rescreening. Dockage does not determine the grade but must be measured and reported on the grade certificate. It is generally the easiest nonwheat material to remove.

First break--The point at the flour mill where wheat leaves the cleaning process and enters the milling process.

Foreign material (FM)--All matter other than wheat found in a sample after the removal of dockage and shrunken and broken kernels. It is the most difficult material to remove from wheat. FM is a grading factor for wheat.

Fumigation--The destruction of pests infesting grain by professional personnel who are trained in the application of fumigants--that is, chemicals that at required temperature and pressure can exist in a gaseous state in sufficient strength and quantities to be lethal to a given pest. Fumigants are some of the most toxic and unique pesticides. Methyl bromide and hydrogen phosphide are the fumigants most commonly used on grain.

Grade--A number designation assigned to grain based on a pre-established set of criteria.

Grade-determining factors--Factors that influence the quality of grain. These factors are taken into account in the grading of grain.

Grain grades and standards--Specific standards of grain quality established to maintain uniformity of grains from different lots. These standards permit the purchase of grain without the need for visual inspection and testing by the buyer.

Intrinsic value--Characteristics critical to the end-use of grain. These are nonvisual and can only be determined by analytical tests. For example, the intrinsic quality of wheat is determined by such characteristics as protein, ash, and gluten content.

New crop survey--A survey of recently harvested wheat that is conducted by the FGIS. The new wheat survey is a measure of the quality of the grain as it enters the grain marketing system.

Non-grade-determining factors--Factors that influence the quality of grain. These factors are not taken into account in the grading of grain and must be reported as information whenever an official inspection is made.

Nonmillable material--All material that is not wheat; also includes shrunken and broken kernels.

Premium--Increases from the base price offered for grain of higher quality characteristics than specified. Premiums are generally calculated for factors that increase the value of the grain.

Protectant--An insecticide used to apply to or mixed with grain to protect it from insect infestation.

Screen cleaner--A series of angled perforated plates or wire screens that separates the grain from particles that are larger than the grain. The screens may be stationary, shaken, or rotated. Removes dockage on the basis of particle size. The screens may differ, but generally coincide with the hole sizes specified in the official U.S. standards for grain. Smaller openings may remove more dockage but also reduce throughput capacity. However, screen cleaners are generally used to remove large particles.

Screenings--The material removed from grain by means of mechanical sizing devices. Screenings generally include broken grain as well as nongrain material removed on the basis of density or particle size.

Shipboard inspection--The official inspection of grain exported from the United States. This inspection is required for all grain exported from the United States. FGIS conducts these inspections.

Shrunken and broken kernels--A grading factor in wheat. Shrunken and broken kernels for wheat are defined as any matter that passes through a 0.064-inch by 3/8-inch oblong-hole sieve. It is measured after dockage is removed.

Subterminal elevator--A grain elevator that receives much of its grain from other elevators. Subterminal elevators act as intermediaries between country elevators, export elevators, and/or domestic mills. Subterminal elevators tend to handle more grain than country elevators, but this is not always true.

Test weight--A measure of grain density determined by weighing the quantity of grain required to fill a 1-quart container and converting this to a bushel (2150.42 cubic inches) equivalent. This term was used from the early beginnings of wheat grades and is related to density but is also influenced by many other factors.

Turning--The movement of grain from one storage tank or silo to another.

Wheat loss--Wheat loss refers to the loss of revenue from the removal of shrunken and broken kernels, FM, and sound wheat from the wheat during the cleaning process. Without cleaning, farmers, elevators, and exporters sell this material on a weight basis as wheat. With cleaning, this nonmillable material can only be sold to the livestock industry as screenings (a byproduct feed) at a much lower price. Thus, wheat loss during cleaning imposes a cost to the elevator. To the extent that dockage is not deducted from the total weight then, the weight of dockage removed is also included as wheat loss. This can occur if wheat is purchased on a gross weight basis, or if wheat is cleaned to a point where the amount of dockage is below the level where it becomes nondeductible.

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Appendix A: Methods and Procedures

There are two general sources that provide information on the costs of cleaning wheat: (1) surveys of producers, commercial elevators, and flour millers; and (2) economic engineering studies. Surveys can provide information on the cost of cleaning under current conditions from individuals who are most familiar with cleaning wheat. However, information obtained from the surveys does not include data on fixed costs or wheat losses from cleaning. Engineering studies have the advantage of examining a wide range of practices. Such studies permit the estimation of cleaning costs for dockage levels not currently observed in the marketplace. Engineering studies have been criticized for generating cost estimates based upon unrealistically efficient operating conditions and extrapolating beyond the range of the test results, but the estimation and extrapolation most frequently reflect the lack of information and the need to address an issue.

Wheat cleaning costs at commercial elevators were estimated using both surveys and engineering studies as data sources. The data for this report come from surveys of onfarm, commercial elevator, and flour mill cleaning practices conducted by producer and industry associations, and economic engineering studies of grain cleaning conducted at Oklahoma State University (OSU) and North Dakota State University (NDSU). Use caution when comparing the results from the different analyses because cleaning costs depend on the initial dockage content and target level. These vary by location and type of enterprise.

The survey data provide information on the average dockage and foreign material (FM) in wheat at delivery, the average dockage and FM removed, and the cost of cleaning wheat. The survey results reflect the cost of current cleaning practices with equipment already installed, not the equipment that might be used under different economic or regulatory circumstances. Many questions concerning wheat cleaning involve cleaning to levels not currently observed. For this reason, engineering studies were used to estimate the fixed costs and the costs associated with wheat lost during cleaning.

Onfarm Survey

The University of Illinois surveyed farmers about their ownership of grain cleaners. A postcard questionnaire was included in the May 1991 issue of *The Wheat Grower*, a publication of the National Association of Wheat Growers (NAWG). From 67,000 issues sent to members, 1,171 postcards were returned. Wheat farmers who responded that they owned an onfarm grain cleaner were sent a more comprehensive followup survey. Of the 310 questionnaires sent, 170 were returned. Although responses to the postcard survey were sufficient to make inferences about the extent of onfarm cleaning, the small number of responses to the followup survey were not sufficient to make reliable estimates of the cost of altering onfarm production and harvest practices to provide cleaner wheat, or the cost of cleaning wheat onfarm.

Commercial Elevator Survey

In the spring of 1991, the National Grain and Feed Association (NGFA) conducted a survey of commercial elevators to determine the prevalence of grain cleaning at U.S. elevators and the motivations for cleaning or not cleaning. The survey obtained an estimate of the grain storage and cleaning capacity at U.S. commercial elevators and the cost of current cleaning practices.

NGFA sent surveys to 6,237 commercial elevators registered by the Agricultural Stabilization and Conservation Service (ASCS).[9] These elevators have a registered storage capacity of 8.3 billion bushels. Of those surveyed, 895 elevator operators, representing 14.3 percent of the commercial elevators and 17.5 percent of the storage capacity, returned usable responses. Of these elevators, 646 handled either winter or spring wheat. The survey results permit examination of cleaning practices by commodity, region, operation type, and volume handled.

Country elevators made up 90.6 percent of the respondents handling wheat, with inland terminals, river, and export elevators accounting for the remainder (6.0, 1.8, and 1.5 percent, respectively). Country elevators from the survey handled around 309 million bushels of wheat. The export elevators from the sample handled 359 million bushels of wheat, or about one-third of the 1990/91 U.S. export volume.

The survey data were used to estimate the cleaning capacity and analyze the current cleaning practices of commercial elevators. Most results presented have been weighted by the volume of wheat handled by the respondent. Premiums and discounts faced by the elevator are exceptions.

In determining the U.S. aggregate cleaning capacity, we used storage capacity to derive the national total from the survey results. The total grain storage capacity of the elevators responding to the survey was 1.46 billion bushels, of which 1.08 billion bushels were available at elevators that handled wheat. Given that 73.9 percent of total grain storage capacity was available for storing wheat, it is estimated that the total available storage capacity at elevators handling wheat was 6.14 billion bushels. Using the 673 million bushels of storage capacity available in the responding elevators handling winter wheat, it is estimated that 3.81 billion bushels of storage capacity is available to elevators handling winter wheat. And, given the 177 million bushels of storage capacity reported by the elevators handling spring wheat, 982 million bushels of available storage capacity is estimated for elevators handling spring wheat. These elevators may also handle other grains or more than one class of wheat. Thus, storage capacity at elevators handling wheat may be used to store wheat or other grains.

Flour Mill Survey

The Millers National Federation (MNF) sent a flour millers survey to each of their members. This survey was similar in nature to the NGFA survey, in that information on contract specifications, discounts, and cost of cleaning was requested. The mills responding to the MNF survey accounted for approximately 40 percent of total U.S. flour milling capacity (MNF, 1991).

Oklahoma State University Study

Adams and Anderson, economists at OSU, examined the costs and benefits of cleaning winter wheat. They examined the dockage and FM content in soft red winter (SRW) and hard red winter (HRW) wheat, the cleaner characteristics necessary to remove this material, the cleaning equipment available, wheat loss during cleaning, and the economic variables affecting wheat-cleaning operations. Their analysis examines the response of an individual firm to the amount of dockage removed, quantity of wheat to be cleaned, and the economic parameters facing the firm.

The OSU researchers constructed a model for selecting the cleaner that would optimize the firm's position under a given set of conditions. They used this model to examine the benefits and costs of cleaning winter wheat by an individual elevator. The model was then modified to examine the costs and benefits of cleaning wheat at the State and national level.

Their study examined the effect of changes in wheat price, cleanings value, transportation cost, market

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[9]Since farmer-owned grain pledged under price support loans with the Commodity Credit Corporation (CCC) and stored off-farm must be stored in an approved warehouse, there is a strong incentive for elevator owners in major producing areas to enter into a contractual arrangement known as a Uniform Grain Storage Agreement (UGSA) with CCC whenever inventories of grain under loan are desired or expected. The warehouses on this list comprise virtually all grain storage capacity in the United States.

premiums, labor and energy costs, interest rates, volume cleaned, and dockage content after cleaning on the cost and net benefits of cleaning wheat. This analysis used a set of base conditions to estimate the benefits and costs of cleaning winter wheat to 0.35-percent dockage content (appendix table 1). The base conditions reflect the average wheat prices and dockage level in the winter wheat region over the past 10 years. The base conditions for equipment use, electricity rates, and labor demand were derived from engineering studies and survey results. To examine the sensitivity of the results to fluctuations in these variables, each of the base conditions was then altered while holding the other conditions constant.

The State and national benefits and costs of cleaning wheat were examined under a series of 16 scenarios. These scenarios varied by the point of cleaning, total amount of wheat to be cleaned, the cleaner type available, and the volume of wheat handled per elevator (national average versus State average). The point of cleaning wheat (country versus the subterminal elevator) has an important effect on the costs and benefits of cleaning. Subterminal elevators generally handle more wheat than country elevators and the transportation savings are greater when cleaning takes place earlier in the market chain. The total amount of wheat to be cleaned has an obvious effect on the cleaning capacity to be acquired and the time the cleaners must run.

The study examines two levels of cleaning: (1) all wheat not fed to livestock is cleaned, and (2) all wheat exported is cleaned. If all nonfeed wheat must be cleaned at elevators, a much larger capital investment in cleaning

Appendix table 1--Parameters used in engineering studies

Parameters	Units	Oklahoma State University (winter wheat)	North Dakota State University (spring wheat)
Price of wheat	$/bu	3.00 [2.00-4.00]	2.24 country 3.36 export (126.50/ton)
Value of cleanings (f.o.b. local)	$/cwt	2.00 [0-4.00]	1.50 [1.00-2.00]
Operating labor wage	$/hr	6.00 [4.00-10.00]	7.71 country 35.00 export
Supervisory labor wage	$/hr	13.00	NA
Electric rate	$/kwh	.105 [0-.20]	.05
Hours of operation	Hrs/yr	1,000	700 [350-1,050]
Wheat loss	%	.75-1.1	.7 [.1-1.1]
Premium for cleaned wheat	$/bu	0 [0-.04]	NA
Transportation rate	$/bu	0.75 [0-2.00]	.30-1.00
Beginning dockage level	%	.85	3 [1.0-5.0]
Target level of dockage	%	.35 [0-.8]	.4 [.1-1.0]

[ ] = Range.
f.o.b. = free on board.
NA = Not applicable.

equipment and more operating time would be required than if only wheat destined for export is to be cleaned. Restrictions on the cleaners available for elevators were also examined. Some regions require more specialized cleaning equipment because dockage contains hard to remove material. Restrictions were placed on the cleaners in the regions with specialized cleaning equipment, increasing the cleaning costs.

The effects of alternative assumptions concerning the volume handled by each elevator were examined. The country elevators were first assumed to handle 370,000 bushels of wheat per year. This assumption was then modified using the State average volume handled reported by country elevators responding to the NGFA survey. A similar set of assumptions was applied to subterminal elevators, except that they were originally assumed to handle 3 million bushels of wheat each year. The different assumptions concerning wheat volume affect the cleaner selected, cleaning capacity required, and the cleaner operating time.

North Dakota State University Studies

Four reports were prepared analyzing the cleanliness issue in wheat. The first, *Wheat Cleaning Costs and Grain Merchandising*, by Scherping, Cobia, Johnson, and Wilson, presented cleaning costs at country and export elevators for durum, hard red spring (HRS), and white wheat. Economic engineering costs were estimated from surveys of grain cleaner manufacturers and elevator managers for screen and disc-cylinder cleaners. A representative cleaner, typical for country and export elevators, was used as the basis for the analysis. Cost estimates were based on an assumed utilization rate of 700 hours each year, wheat loss of 0.4 percent, and beginning and ending dockage levels of 3 percent and 0.4 percent, respectively (appendix table 1). Alternative assumptions for utilization, wheat loss, and dockage levels generated cost functions. Revenue from screenings sales and transportation savings were varied to measure the margin between these cleaning benefits and cleaning costs.

Wheat Cleaning Decisions at Country Elevators, by Johnson, Scherping, and Wilson, analyzed the wheat cleaning and blending decisions at a country elevator. They developed a mathematical programming model for cleaning within the broader framework of a blending and merchandising problem. By incorporating alternatives to cleaning, the model provides a more realistic basis for assessing the effect of particular parameters and for evaluating how alternative regulations would affect the economics of cleaning. The model maximizes net revenue for the firm from wheat sales and screenings, less cleaning and transport costs. Simulations using actual quality data from two significantly different crop years illustrate the sensitivity of model results. The researchers determined the discount necessary to induce cleaning given different dockage levels and screenings prices. They also evaluated the impact of adding limits on dockage to the grade standard.

The third report, *Measuring the Impact of Dockage on Foreign Demand for U.S. Wheat*, by Johnson and Wilson, evaluated the costs and benefits of cleaning prior to export. They developed two optimization models, one for the foreign importer and the other for a U.S. export firm. The importer can purchase wheat either from a single competitor and/or the United States, whose wheat has differing dockage and other quality attributes. The importer minimizes net costs (the price of wheat, cleaning costs, and other import costs) given that minimum quality requirements are satisfied. The model assumes no response by competitors to changes in U.S. quality or price.

The exporter model represents a single vertically integrated U.S. export firm whose objective is maximization of net revenues from wheat sales. Net revenues include transportation savings and screenings sales, but subtracts cleaning costs. The exporter chooses the dockage level offered for sale and whether it is cleaned at the port or further back in the supply pipeline.

Both models are solved jointly by having the U.S. exporter choose a price at which it will sell and the dockage level; the importer takes the U.S. price as given. This simulation produces a level of wheat imports from the United States and the optimal level of dockage for that country.

The last report, *Impacts of Alternative Policies Regulating Dockage*, by Wilson, Scherping, and Johnson, estimated aggregate costs and benefits of policy changes for HRS, durum, and white wheat. They calculated the aggregate net cost of cleaning to 0.7-percent dockage (the base case) versus 0.5-percent and 0.2-percent dockage (a more restrictive grade standard). Their analysis produces aggregate net costs for 2 crop years under two scenarios: (1) wheat is required to be cleaned at the point of first sale, and (2) only wheat that is exported must meet the dockage limit.

Methodology Differences Between OSU and NDSU

The OSU and NDSU studies generally use similar ways to calculate the costs and benefits of owning and operating grain cleaners. The differences and the reasons for them are given below.

Both studies examined operating specifications from a number of different grain cleaner manufacturers and models. The NDSU study chose two cleaners (from a sample of 14) representative of the type most likely to be found in country (disc-cylinder) and export elevators (high-capacity screen). The OSU study varied parameters to find the distribution of cleaning costs for each of 13 different grain cleaners. Maintenance, power, operating capacity, and investment cost will all vary, depending on the cleaner model selected.

The NDSU study used a standard value of 13.32 percent for the interest rate, which determines the opportunity cost of the investment. The OSU study varied the interest rate from 8 to 16 percent but settled for 12 percent as their standard value.

The NDSU study did not include the cost of insuring the cleaning equipment. However, the OSU study used an insurance cost of $3.50 per $1,000 of replacement value per year, which is a negligible cost item.

The OSU study assumed a cleaner utilization rate of 1,000 hours per year. The NDSU study determined the sensitivity of cleaning costs to three annual utilization rates: 350 hours, 700 hours, and 1,050 hours.

NDSU derived cleaning cost estimates for three beginning dockage levels: 5 percent, 3 percent, and 1 percent. Target dockage levels were 1.0 percent, 0.7 percent, 0.4 percent, and 0.1 percent. The situation most probable to occur in practice is a reduction from 3 percent to 0.7 percent. OSU derived cleaning cost estimates for a reduction from 0.85 percent to a range of target dockage levels ranging between zero and 0.8 percent. OSU chose 0.35 percent as their standard ending dockage.

The NDSU study surveyed elevator managers about the wheat loss associated with cleaning to different target levels. They use these estimates, ranging from 0.2 percent to 1.0 percent, to determine the added cost of cleaning. The NDSU report valued the loss of HRS wheat, depending on the location (for 1990/91), $2.48 per bushel at North Dakota country elevator and $3.67 at export elevator. The merchandising margin includes $1.00 transportation cost plus $0.20 handling cost. OSU varied the price of winter wheat between $2-$4 per bushel to test the sensitivity of this parameter on wheat-cleaning costs, but assumed $3.00 per bushel for all other standard values. Wheat loss at winter wheat elevators was a function of the cleaner which minimized the cost of cleaning. The wheat loss with these cleaners ranged from 0.6 to 1.6 percent. OSU assumed that the merchandising margin was 30 cents per bushel higher (20 cents transportation, 10 cents handling) between country and terminal elevators.

The savings from lower transportation expenses were varied between 0-2.0 cents per bushel in the OSU study. The freight rates are different for truck and rail carriers with each mode assumed to account for half of the volume shipped. The NDSU study used $0.30, $0.60, and $1.00 per bushel, with the latter being closest to current unit train freight rates between North Dakota and the Pacific Northwest. They did not allocate between truck and rail as the latter accounts for most of the spring wheat shipped.

The value of screenings in the OSU study was allowed to vary between $0-$4 per hundredweight (cwt), with a standard value of $2.00 per cwt. The latter value was based on NGFA survey responses for winter wheat areas. The NDSU study determined net cleaning costs based on screenings prices of $1.00, $1.50, and $2.00 per cwt. The standard values selected for deriving cost estimates were $0.50 per cwt for 1987 and $1.50 per cwt for 1990. The values for these years were based on responses to a marketing survey of North Dakota elevators.

The NDSU study assumed no benefits in storage from cleaning HRS and durum wheat. Due to the cold winters, fewer elevators in the northern United States have insect problems. The OSU study reported that the insect management benefits from cleaning winter wheat (50 percent was stored an average of 6 months) was $0.002 per bushel. If insect damage progresses beyond the fines core of the storage structure, savings could be higher. However, OSU suggested that this estimate overstates the savings as it applies to high-risk, high-temperature areas. They also noted that there are other methods to reduce storage losses. These may be more cost-effective than cleaning, depending on the situation. Aeration cost savings averaged only $0.00027 per bushel.

Appendix B: Winter Wheat

Wheat of different classes has different physical and intrinsic quality characteristics. The differences in these characteristics are due to different harvesting and production practices, growing conditions, and genetic traits that can affect wheat cleanliness and wheat-cleaning costs. This appendix examines the costs and benefits of cleaning winter wheat.

Sixty-seven percent of the wheat produced in the United States over the last 10 years was winter wheat. Winter wheat is planted and germinates in the fall and becomes dormant during the winter. The wheat matures and is harvested in the spring. By germinating in the fall, winter wheat can suppress many of the weeds that germinate in the spring, thereby reducing the amount of weed material harvested with the wheat. Winter wheat is typically field dried while standing before it is harvested. These growing conditions and harvest practices tend to reduce the amount of weeds, seeds, and dirt harvested with the wheat. This, in turn, helps control dockage levels.

The United States produces three major classes of winter wheat, hard red winter (HRW), soft red winter (SRW), and white wheat. These classes of wheat are grown in different regions, have different marketing channels, and possess different milling and baking properties. For these reasons, HRW and SRW wheat will be discussed separately. Elevators in the white wheat areas of the Pacific Northwest cleaned a minimal amount of wheat and are not emphasized in this report (NGFA, 1991).

Hard Red Winter

Dockage and foreign material (FM) in HRW decline as it moves through the marketing system from the farm to the mill or export terminal (appendix table 2 and appendix fig. 1). Grain cleaning, contract specifications, and market incentives are the three reasons that wheat becomes cleaner as it moves toward the final purchaser.

The NGFA survey found that 16 percent of elevators that handled primarily HRW cleaned over 35 percent of the wheat they handled. During cleaning, they removed 0.9 percent of the gross weight as dockage and FM.[10]

Contract specifications influence the cleanliness of wheat by placing limitations on the dockage a buyer will accept. An examination of export contracts reveals that numerous foreign customers of U.S. HRS wheat specify maximum dockage levels they will accept (Adam and Anderson, 1992). Further, in each year between 1986 and 1990, well over 90 percent of U.S. HRW exported was sold as grade 2, restricting allowable FM to less than 1 percent (USDA, 1991). A survey of U.S. flour mills confirmed that the majority of mills will refuse wheat with elevated levels of dockage and FM. These specifications encourage grain handlers to provide cleaner grain.

Data from USDA inspections support these observations. Data from USDA's *new crop survey* and *shipboard inspections* suggest exporter contract specifications may have an impact on HRW dockage levels (appendix table 3). The national average dockage found during each new crop survey of HRW since 1987 was greater than or equal to 0.8 percent, the maximum allowable dockage permitted in shipments received by China, Japan, and India (USDA, 1987-90, Adam and Anderson, 1992).[11] The corresponding dockage level in HRW exported from the United States is less than or equal to 0.7 percent, more than meeting these contract specifications. Thus, the export contract specifications from these major customers may have had an influence on dockage levels in exported HRW.[12]

Differences in the wheat market also help explain changes in dockage and FM levels. Different end-users have different cleanliness requirements and cleaning capabilities. U.S. flour mills require extremely low dockage and FM levels at the *first break*[13] (appendix table 4), but an examination of their contract specifications shows that domestic flour mills tend to have less stringent dockage and FM specifications than wheat importers. The gap between the contract specifications for dockage and FM and mill cleanliness requirements indicates that U.S. flour mills have the capability to efficiently clean wheat. Flour mills, therefore, are unlikely to offer premiums for HRW with a low dockage or FM content. Similarly, the feed market does not require low-dockage wheat, so the feed industry places little premium on wheat cleanliness.

In the export market, on the other hand, the longer distances involved increase the transportation costs associated with shipping nonwheat material. In addition, different cleaning capabilities, the use of FGIS inspections, and other factors can make cleaner wheat more attractive to foreign buyers than domestic customers. Together, these economic forces create market incentives that encourage grain handlers to channel wheat to markets according to its cleanliness.

Domestic flour millers are well aware of the wheat quality coming out of different areas of the country and purchase accordingly. Surveys by the Office of Technology Assessment and Millers National Federation (MNF) on quality attributes indicated that two-thirds or more of domestic millers did not specify dockage limits in their purchasing contracts. Very few U.S. millers paid premiums for low-dockage wheat. According to the MNF survey, the millers that did pay extra for cleaned wheat had older cleaning equipment and higher cleaning costs than the industry average. Most millers said it costs no more for them to clean wheat

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[10]It is likely the wheat that was cleaned contained higher than average levels of dockage and FM. For this reason, the amount of dockage in wheat after cleaning is unknown.

[11]However, wheat delivered with dockage levels that exceed the maximum amount specified in a contract might be accepted with a discount or other penalty.

[12]While FM is a grade-determining factor for wheat, the level of FM in HRW does not seem to be an issue with importers. Over the same time period, the FGIS new crop inspections found the national average for FM to be less than 0.4 percent. This is an FM level that satisfies the standards for No. 1 wheat.

[13]When wheat enters the milling process.

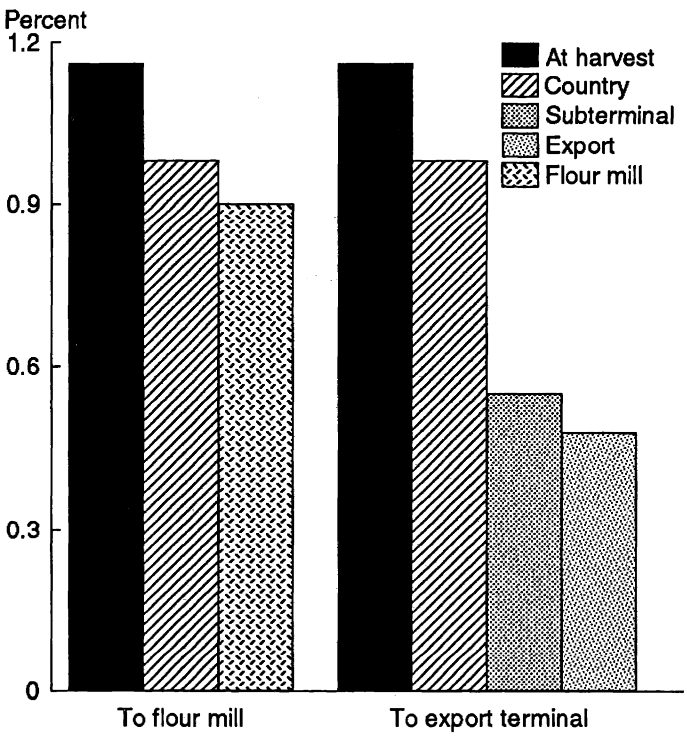
Appendix table 2--Dockage and foreign material in hard red winter, by operation, 1990-91

Type of operation	Observations	Estimated dockage		Observations	Estimated foreign material	
	Number	------*Percent*[1]------		*Number*	-----*Percent*[1]-----	
At harvest[2]	384	1.16	(0.08)	336	0.86	(0.08)
Country	204	.98	(.07)	181	.64	(.06)
Subterminal	30	.55	(.06)	29	.38	(.06)
Export	4	.48	(.15)	4	.37	(.09)
Export (FGIS)[3]		.6-.7			.2-.3	
Flour mill		.90			.48	

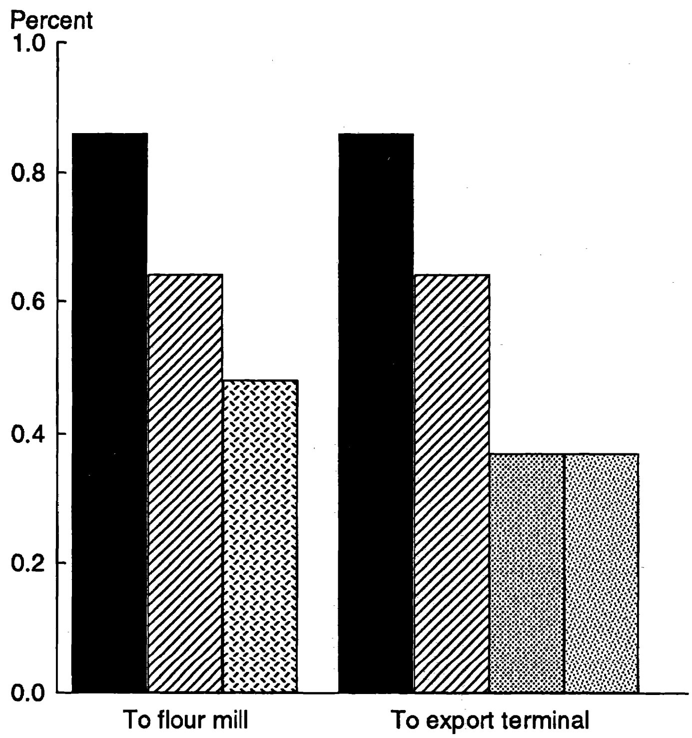
() = Standard error of the mean.
[1]Averages weighted by volume of wheat handled.
[2]At-harvest averages for all winter wheat are unweighted.
[3]FGIS-data range of annual average between 1984-91.
Source: NGFA, 1991, commercial elevator survey.

Appendix figure 1

Dockage in hard red winter wheat: Through the marketing channel



Foreign material in hard red winter wheat: Through the marketing channel



Source: Onfarm, commercial elevator, and flour mill surveys (NAWG, NGFA, MNF).

Appendix table 3--Contract specifications for hard red winter wheat, 1981-90

Country	Class	Grade	Dockage
			Percent
China	Hard red winter/soft red winter	U.S. No. 2	Max 0.8 (0.1 nondeductible)
Colombia	Hard red winter	U.S. No. 2[1]	Max 0.8
Finland	Hard red winter	U.S. No. 2	Max 0.5
India	Hard red winter	U.S. No. 2	Max 0.8 (0.5 nondeductible)
Iraq	Hard red winter/soft red winter	U.S. No. 2	Max 1.0 (0.5 nondeductible)
Israel	Hard red winter	U.S. No. 2	Max 1.0
Japan	Hard red winter	U.S. No. 2	Max 0.8 (0.5 nondeductible)
Jordan	Hard red winter	U.S. No. 2	Max 1.0
Mexico	Hard red winter	U.S. No. 2	Max 1.0 (nondeductible)
South Africa	Hard red winter	U.S. No. 2	Max 1.0
Sri Lanka	Hard red winter/northern spring	U.S. No. 2	Max 0.9
Tunisia	Hard red winter/northern spring/ soft red winter/soft white wheat	U.S. No. 2	Max 1.0
USSR	Hard red winter/northern spring/ dark northern spring	U.S. No. 2	Max 1.0 (0.5 nondeductible)

[1]The maximum foreign material for U.S. No. 2 wheat is 1.0, but Colombia specifies a maximum of 0.50 percent per sublot.
Source: Adam and Anderson, 1992.

Appendix table 4--Dockage and foreign material at the flour mill, 1990-91[1]

	Dockage and FM content at first break		Amount removed by first break	
Wheat	Dockage	Foreign material	Dockage	Foreign material
		Percent[1]		
Hard red winter	0.01	0	0.48	0.89
Soft red winter	.02	.03	.58	.79

[1]Averages weighted by volume of wheat handled.
Sources: NGFA, 1991, commercial elevator survey, and MNF, 1991 (flour mill survey).

with 1-percent dockage than it does for 0.1-percent dockage wheat. However, foreign millers are at a disadvantage because they have much less knowledge about the U.S. crop and are limited to only a few suppliers. They use dockage in their standard contracts more frequently.

Market Discounts and Premiums

Discounts for wheat with a high dockage and/or FM content and premiums for wheat with a low dockage and/or FM content are the primary means that demand for clean wheat is communicated in the domestic market. Discounts are used more frequently than premiums.

Weight Deductions

Agents within the wheat marketing system use prices, discounts, and premiums to signal the value they place on wheat and different quality attributes. Sixty-one percent of the commercial elevators and all flour mills handling primarily HRW deducted the dockage content by weight over some level. Two-thirds of the HRW elevators that used a weight deduction indicated dockage above 0.5 percent was subtracted from HRW delivered (appendix fig. 2). A quarter of the elevators indicated all dockage was deductible. The use of weight deductions, if not accompanied by price discounts, suggests that within certain limits, dockage has no net value but does not degrade the value of HRW. The average dockage level received by elevators that purchase on a gross weight basis is 0.9 percent compared with 1.3 percent for net weight purchasers.

Price Discounts

Price discounts for dockage can be used either in conjunction with or instead of weight deductions. Price discounts increase as the level of nonwheat material increases. For HRW, price discounts for dockage were observed less frequently than weight deductions. Three-quarters of HRW elevators received no price discount for dockage, even at levels above 3 percent. Eighty-nine percent of the HRW elevators had no discount for 2-percent dockage.

Grain elevators tend to use price discounts for FM in HRW (appendix table 5). Two-thirds of the elevators handling HRW had a price discount for wheat with 1-percent FM. Price discounts increase as the level of nonwheat material increases. In the 1990/91 marketing year, the commercial elevators reported an average discount of 0.9 cents per bushel for 1-percent FM, the grade limit for No. 2 HRW (appendix table 5). Discounts can often vary from year-to-year by more than 1 cent per bushel for 1-percent FM (Scherping and Wilson, 1991).

The relationship between price discounts at country and subterminal elevators are different for dockage and FM. The available data suggest that country elevators are more likely to face price discounts for dockage than export terminals, and that these discounts tend to begin at lower levels (appendix table 5). Conversely, at FM levels above 1 percent, the discount facing subterminal elevators is greater on average than that facing country elevators (appendix table 5). The higher discounts may imply that subterminal elevators have a larger role in exporting wheat and, therefore, sell more grain using official USDA grades and standards. Well over 90 percent of HRW is sold as U.S. No. 2 HRW, so wheat with more than 1-percent FM must be cleaned, blended, or sold at a lower grade. The higher discounts facing subterminal elevators for FM over 1 percent likely reflect the export demand for No. 2 HRW.

Premiums for wheat with a low dockage or FM content do not play a large role in the market. Only about 1 percent of the elevators sampled paid premiums for wheat with less than 1-percent dockage or foreign material. The elevators that offered premiums paid an average of 1 cent per bushel.

Soft Red Winter Wheat

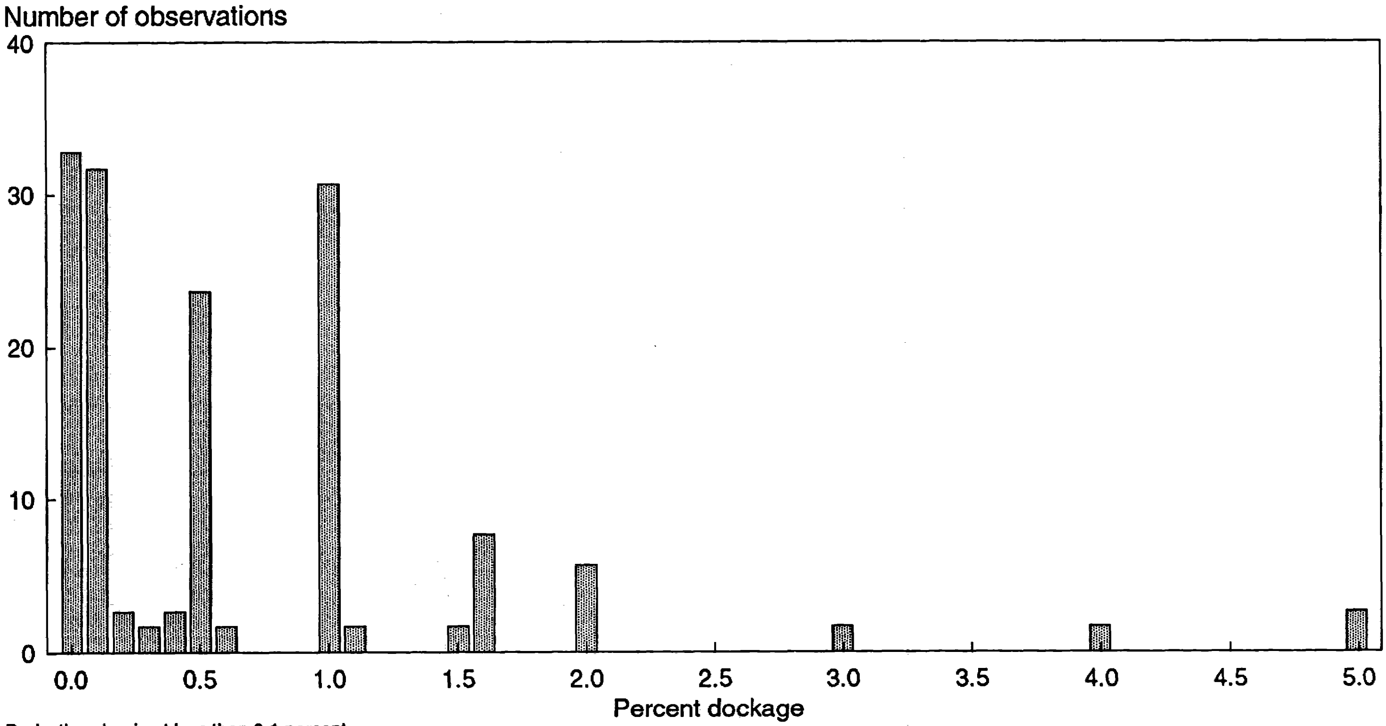
SRW represents 20 percent of the wheat produced in the United States. SRW is produced over a wider geographic area than HRW, so the production and harvesting practices used are more varied. Sixty percent of SRW is produced in Illinois, Missouri, Ohio, Arkansas, and Indiana; 18 States account for the remaining 40 percent.

As with HRW, the dockage and FM content in SRW decreased as wheat moved from the farmgate to the processor. Further, SRW delivered to export elevators was cleaner than SRW delivered to flour mills. The average dockage content of SRW at harvest was 1.2 percent. The dockage content reported in the NGFA and MNF surveys declined to 0.8 percent at delivery to flour mills and 0.5 percent at delivery to export terminals (appendix table 6 and appendix fig. 3). Similarly, the FM content in SRW was 0.9 percent at harvest, declined to 0.6 percent upon delivery to flour mills, and declined to 0.3 percent upon delivery to export elevators (USDA, 1986-90). The same general trend holds when data from FGIS shipboard inspections are used, although these data suggest the elevators underestimate the amount of dockage and overestimate the amount of FM.

As with HRW, the increasing cleanliness of SRW is a result of a combination of wheat cleaning at elevators, contract specifications, and reaction of elevators to market incentives.

Appendix figure 2

Beginning of dockage weight deductions: Hard red winter wheat elevators



Deductions begin at less than 0.1 percent.
Source: NFGA, 1991, commercial elevator survey.

Appendix table 5--Average discounts for hard red winter dockage and foreign material at commercial elevators by operation, 1990-91

Type of operation	Elevators	0.5	1.0	1.5	2.0	2.5	3.0
		Percent of dockage					
	Number	----*Cents/bushel*----					
Country	88	0.11	0.38	0.73	1.18	1.54	1.53
Subterminal	20	0	0	.10	.20	.30	.40
Export	2	0	0	0	0	0	0
National	110	.09	.31	.60	.98	1.27	1.27
		Percent of foreign material					
		0.5	1.0	1.5	2.0	2.5	3.0
		----*Cents/bushel*----					
Country	106	.30	.91	1.56	2.36	3.06	4.43
Subterminal	21	.05	.74	2.14	2.57	3.52	5.53
Export	3	.17	.83	2.50	3.00	3.67	7.17
National	130	.26	.88	1.67	2.40	3.15	4.67

Source: NGFA, 1991, commercial elevator survey.

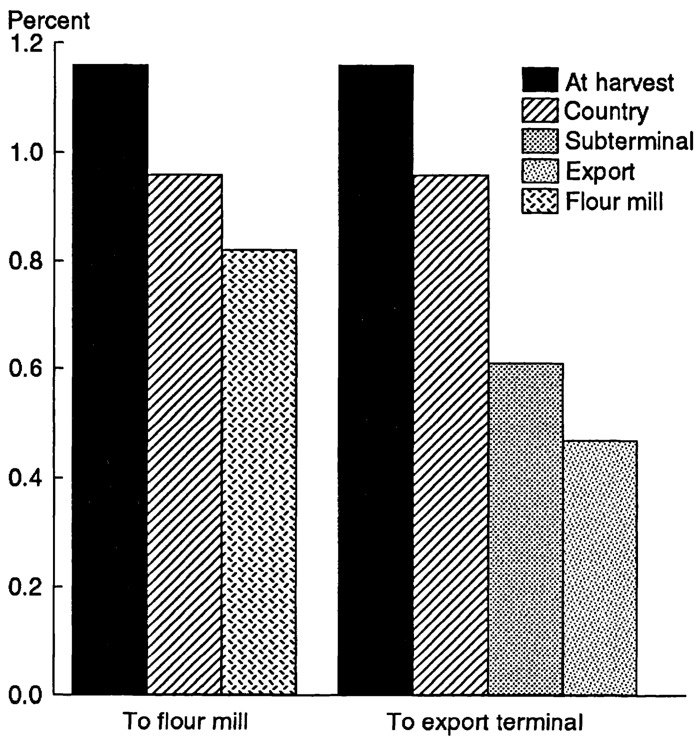
Appendix table 6--Dockage and foreign material in soft red winter by operation, 1990-91[1]

Type of operation	Observations	Estimated dockage		Observations	Estimated foreign material	
	Number	*Percent*		*Number*	*Percent*	
At harvest[2]	384	1.16	(.08)	336	0.86	(.08)
Country	156	.96	(.08)	135	.60	(.07)
Subterminal	11	.61	(.12)	11	.35	(.11)
Export	4	.47	(.10)	4	.34	(.06)
Export (FGIS)[3]		.7-.8			.20	
Flour mill		.82			.61	

() = Standard errors of the mean.
[1]Averages weighted by volume of wheat handled.
[2]At-harvest averages for all winter wheat are unweighted.
[3]FGIS-range of annual average between 1984-91.
Sources: NGFA, 1991, commercial elevator survey, and MNF, 1991 (flour mill survey).

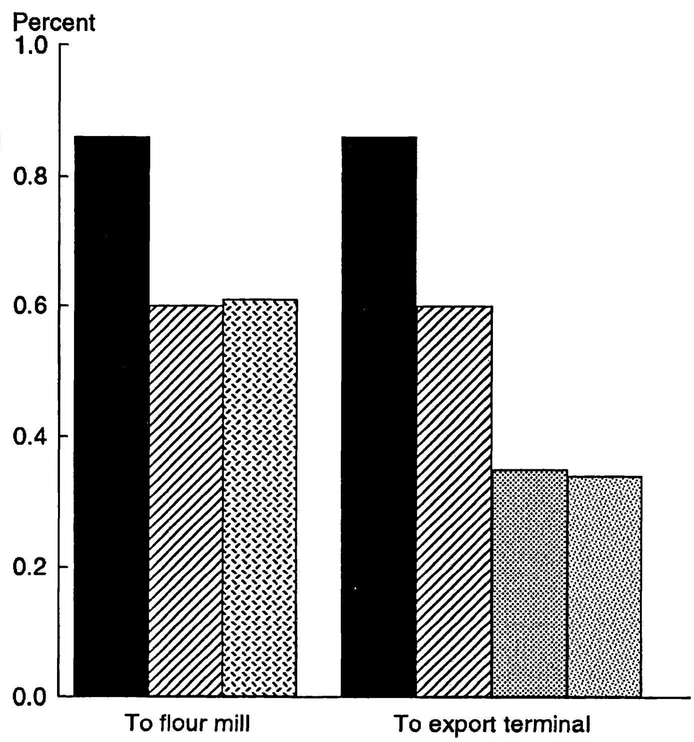
Appendix figure 3

Dockage in soft red winter wheat: Through the marketing channel



Source: Onfarm, commercial elevator, and flour mill surveys (NAWG, NGFA, MNF).

Foreign material in soft red winter wheat: Through the marketing channel



Market Discounts and Premiums

Discounts for SRW wheat with a high dockage and/or FM content and premiums for wheat with a low dockage and/or FM content are the primary means that demand for clean wheat is communicated in the domestic market. Discounts are used more frequently than premiums.

Weight Deductions. Seventy-four percent of the commercial elevators and all flour mills handling primarily SRW deducted (above some percentage) the dockage content by weight. Four-fifths of the SRW elevators that used a weight deduction indicated that dockage above 0.5 percent was subtracted from SRW delivered (appendix fig. 4). Thirty percent of the elevators indicated the weight deduction applied for all dockage.

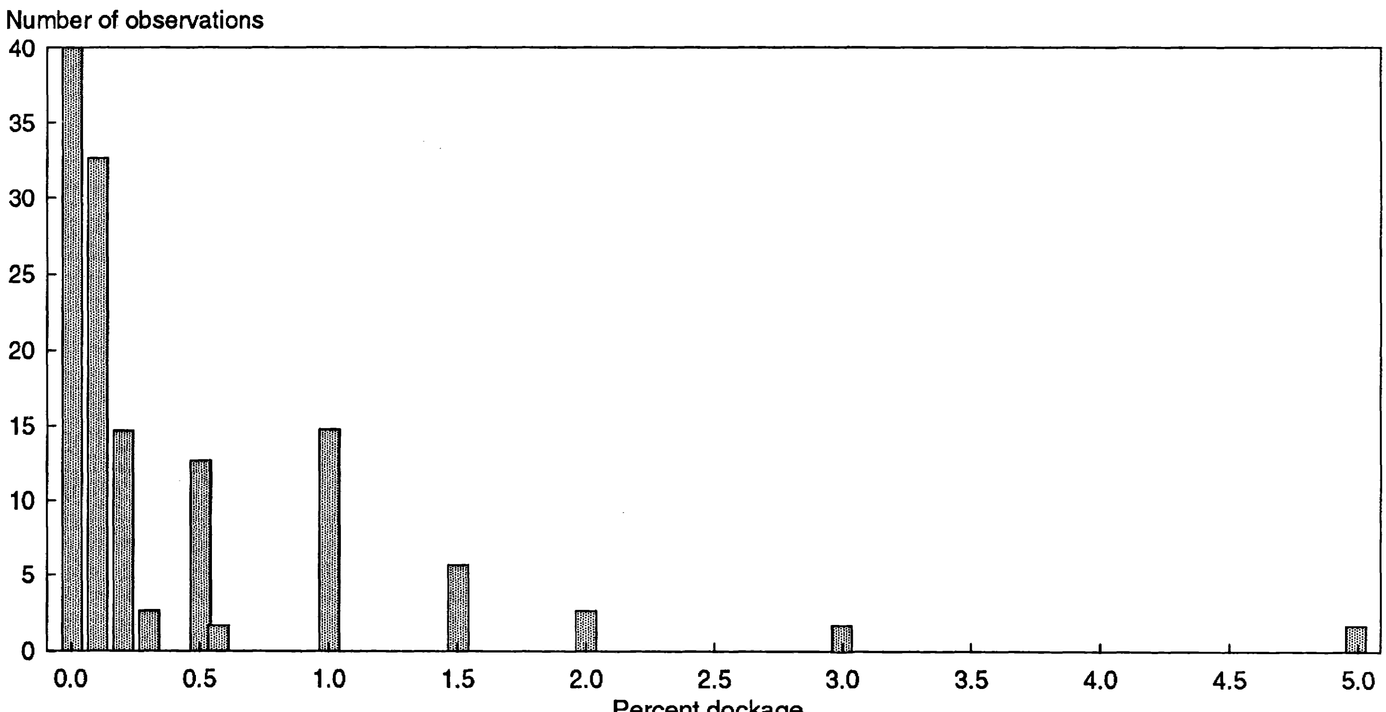
Price Discounts. Price discounts for dockage can be used either in conjunction with or instead of weight deductions. Price discounts increase as the level of nonwheat material increases. Price discounts for dockage in SRW were observed less frequently than weight deductions. Eighty-six percent of SRW elevators received no price discount for dockage, even at levels above 3 percent.

Grain elevators tend to use price discounts for FM in SRW (appendix table 7). Over half of the elevators handling SRW had a price discount for wheat with 1.5-percent FM. In the 1990/91 marketing year, the commercial elevators reported an average discount of 0.4 cents per bushel for 1-percent FM, the grade limit for No. 2 HRW (appendix fig. 5). The discount jumped to 1.1 cents for 1.5-percent FM. As was noted earlier, discounts can vary from year to year by more than 1 cent per bushel for 1-percent FM (Scherping and Wilson, 1991).

The relationship between price discounts at country and subterminal elevators for SRW is different than for HRW (appendix table 7). The data available suggest that country elevators face price discounts for dockage in SRW while subterminal elevators do not. Also, discounts for FM are nearly equal for both country and subterminal elevators (the HRW discounts were higher for subterminal elevators). It is difficult to explain these differences. The FM level in exported SRW is 0.2 percent, 0.1 percentage points lower than for HRW, making it marginally easier to blend. However, it is unlikely that the higher FM discounts to HRW subterminal elevators are based on a 0.1-percentage point difference in FM. It is more likely that the differences are a function of small data sample and may disappear with more observations.

The rapid rise in discounts as the FM level exceeds 1.5 percent is easier to explain. The higher discounts reflect

Appendix figure 4
Beginning of dockage weight deductions: Soft red winter wheat elevators



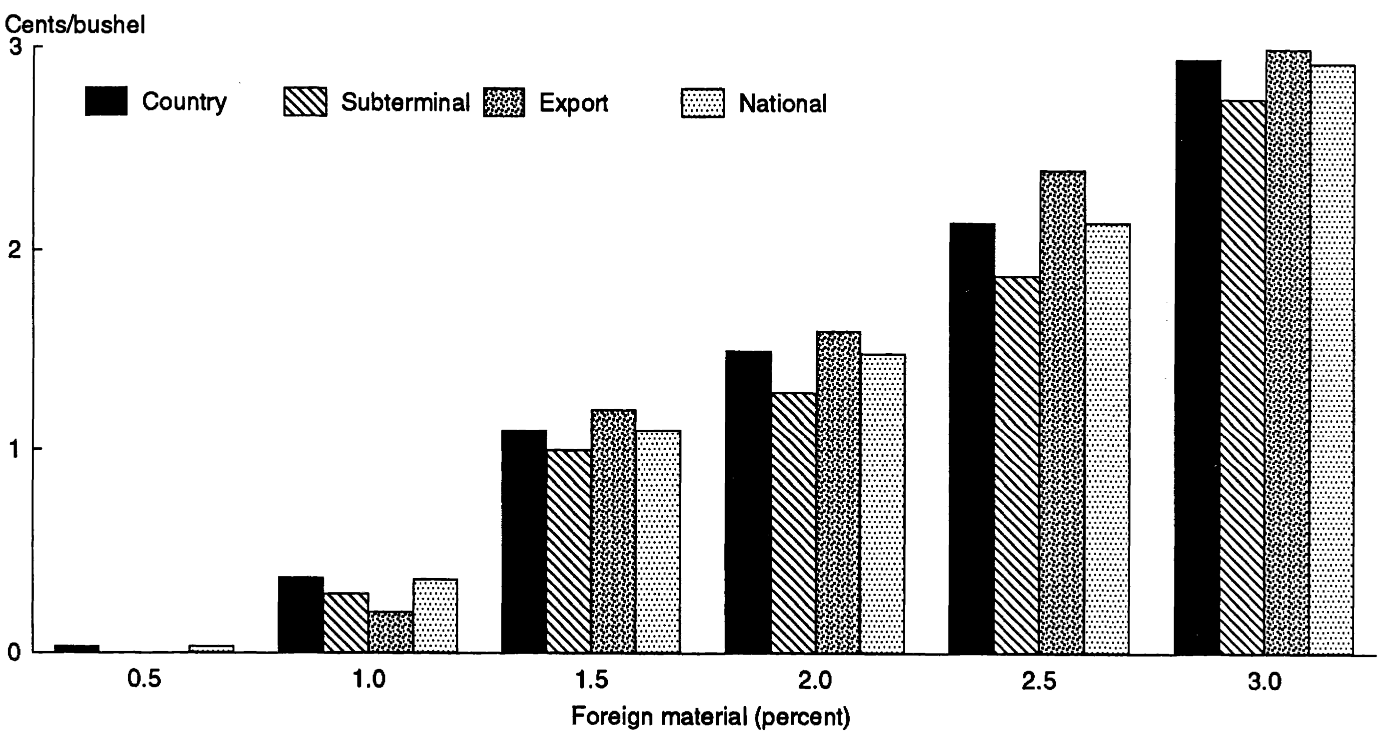
Deductions begin at less than 0.1 percent.
Source: NFGA, 1991, commercial elevator survey.

Appendix table 7--Average discounts for soft red winter wheat dockage and foreign material at commercial elevators by operation, 1990-91

Type of operation	Elevators	Percent of dockage					
		0.5	1.0	1.5	2.0	2.5	3.0
	Number	---*Cents/bushel*---					
Country	89	0.18	0.30	0.39	0.51	0.62	0.71
Subterminal	6	0	0	0	0	0	0
Export	4	0	0	0	0	0	0
National	99	.16	.27	.35	.45	.56	.64
		Percent foreign material					
		0.5	1.0	1.5	2.0	2.5	3.0
	Number	---*Cents/bushel*---					
Country	87	0.03	.37	1.10	1.50	2.14	2.95
Subterminal	8	0	.29	1.00	1.29	1.88	2.75
Export	5	0	.20	1.20	1.60	2.40	3.00
National	94	.03	.36	1.10	1.49	2.14	2.93

Source: NGFA, 1991, commercial elevator survey.

Appendix figure 5
Foreign material price discounts: Soft red winter wheat



Source: NGFA, 1991, commercial elevator survey.

the fact that well over 90 percent of SRW is sold as U.S. No. 2 grade. SRW with more than 1.5 percent FM is more difficult to clean and/or blend and may have to be sold at a lower grade. The higher discounts facing elevators for FM over 1.5 percent likely reflect the export demand for No. 2 SRW.

Premiums for wheat with a low dockage or FM content do not play a large role in the market. Less than 1 percent of the elevators sampled paid premiums for wheat with less than 0.5-percent dockage. The buyers that offered premiums paid an average of 1 cent per bushel. No buyer offered a premium for low-FM SRW.

Wheat Cleaning

An examination of the dockage and FM discounts for wheat provides a likely explanation for the location of grain cleaning at commercial elevators. Elevators that clean wheat on a regular basis face higher discounts than elevators that do not clean wheat. This supports the idea that the elevators use prices to create a market that communicates the grain quality characteristics demanded. Because elevators are an integral part of that market, they respond to these signals by providing wheat with these quality characteristics.

A further indication that grain markets are efficiently distributing wheat is that both HRW and SRW elevators that have cleaners receive wheat with more dockage and FM than elevators without cleaners (appendix table 8). However, it is not clear whether the cleaners are installed at an elevator because it receives high-dockage wheat or the high-dockage wheat goes to an elevator because it has a cleaner. One would expect that dirtier wheat would be more likely to be delivered to an elevator with a cleaner. This observation suggests that incentives offered by the marketing system lead wheat with higher levels of nonmillable material to elevators that can clean it. Elevators that use cleaners face a higher average dockage discount than those that do not clean.

Regional Variation

The dockage and FM content of SRW varies more across regions than HRW. For SRW, the highest average dockage at delivery to elevators is found in the Delta States (1.9 percent) and the lowest in the Corn Belt (0.6), shown in appendix tables 9 and 10. SRW from the Delta States also had the highest average FM content (1.0 percent), while SRW from the Corn Belt had the lowest average FM content (0.4 percent).

The factors contributing to a higher average dockage and FM content in SRW in the Delta States are largely the same as those contributing to higher dockage and FM levels for HRW in the Mountain States, although the role they play is somewhat different. Different crop rotations, climatic conditions, and cultural practices all contribute to differences in regional dockage and FM content. The Delta States double crop wheat more often than other regions. This leads to more weeds and nonwheat growth. A warmer and more humid climate provides conditions that are conducive for competing vegetative growth. Further, SRW wheat yields are lower in the Delta States than in the Corn Belt, so farmers have less economic incentive to apply herbicides and/or cultivate to control weeds. These factors combine to explain higher dockage and FM content in SRW from the Delta States, and conversely lower dockage and FM content from the Corn Belt.

Cost of Cleaning Winter Wheat

The cost of cleaning wheat varies, depending upon a number of factors: the cleaner used, the type of nonwheat material to be removed, the initial and target dockage levels, the wheat price, and the cost of energy, labor, and other inputs. The elevator has control over the cleaner used and the target level of dockage. Once the cleaner has been installed, the elevator can only control the target dockage level.

The cleaner used affects cleaning costs through finance expenses, operating capacity, cleaning efficiency, and wheat loss. Elevators purchase a grain cleaner by making projections of future demand for cleaned wheat and of future wheat and input costs. Elevators purchase a grain cleaner best suited for their needs. Cleaning costs increase when the size of material to be removed is similar to wheat, the amount of nonwheat material to be removed from wheat increases, and the level of material remaining in the wheat after cleaning decreases. Costs increase because each of these factors increase the amount of sound wheat removed with the nonwheat material, slow the cleaning process, and increase the operating time of the cleaner. Because some sound wheat is lost during cleaning, the price of wheat affects the cost of cleaning. Thus, as wheat prices increase the cost of cleaning increases.

The cost of cleaning winter wheat was estimated using both the OSU engineering analysis and the NGFA survey data. Although the engineering analysis examined the cost of cleaning winter wheat under 16 scenarios, only the scenarios considered realistic and feasible will be discussed here.[14] For these scenarios, the cost of

[14]These scenarios restricted the cleaners available to an elevator to those suited for removing the type of dockage found in their State. These scenarios also simulated the wheat volume handled by the elevators using the State-level estimates obtained from the NGFA survey.

Appendix table 8--Dockage and foreign material received by elevators with and without cleaners, 1990-91

Wheat	With cleaner		Without cleaner	
	Dockage	Foreign material	Dockage	Foreign material
	Percent[1]			
Hard red winter	0.81	0.41	0.58	0.42
	(.18)	(.10)	(.06)	(.06)
Soft red winter	1.50	.99	.74	.45
	(.20)	(.33)	(.07)	(.07)

() = Standard error of the mean. [1]Averages weighted by volume of wheat handled. Source: NGFA, 1991, commercial grain elevator survey.

Appendix table 9--Dockage and foreign material in hard red winter wheat by region, 1990-91

Region	Observations	Estimated dockage		Observations	Estimated foreign material	
	Number	*Percent*[1]		*Number*	*Percent*[1]	
Appalachian	1		---	1		---
Corn Belt	12	0.72	(0.24)	12	0.18	(0.44)
Lake State	---		---	---		---
Mountain	17	1.00	(.35)	16	.85	(.23)
North Plains	152	.60	(.07)	131	.35	(.06)
Pacific	1		---	2		---
South Plains	48	.56	(.09)	48	.43	(.11)
National	233	.60	(.60)	210	.42	(.05)

--- = Categories with less than eight observations are not reported. ( ) = Standard error of the mean. [1]Averages weighted by volume of wheat handled. Source: NGFA, 1991, commercial elevator survey.

Appendix table 10--Dockage and foreign material in soft red winter wheat by region, 1990-91

Region	Observations	Estimated dockage		Observations	Estimated foreign material	
	Number	*Percent*[1]		*Number*	*Percent*[1]	
Appalachian	10			7	104	(0.43)
Corn Belt	116	0.55	(0.06)	98	.38	(.06)
Delta States	13	1.92	(.23)	11	1.04	(.23)
Lake States	18	1.26	(.33)	20	.87	(.20)
Northeast	2		---	2		---
North Plains	2		---	1		---
Southeast	8	1.19	(.13)	9	.84	(.55)
South Plains	2		---	2		---
National	172	.77	(.06)	151	.47	(.07)

--- = Categories with less than eight observations are not reported. ( ) = Standard error of the mean. [1]Averages weighted by volume of wheat handled. Source: NGFA, 1991, commercial elevator survey.

cleaning was estimated at both country and subterminal elevators, both for all wheat exported and all winter wheat excluding that fed to livestock. These scenarios are thought to best reflect the response of the industry to introduction of dockage as a grade-determining standard.

Two primary conclusions were obtained:

- The cost per bushel and the total cost were minimized if winter wheat was cleaned at subterminal elevators. The lower cost was due to reduced capital requirements.

- As the total amount of wheat to be cleaned increased, the total cleaning cost increased and the cost per bushel cleaned decreased. The larger total cost was due to increased operation costs.

The cost was minimized if wheat was cleaned at subterminal elevators because of their lower capital requirements. The average cost per bushel to clean all wheat for export at country elevators was 6.7 cents; 4.3 cents to operate the cleaner and 2.4 cents in fixed costs (appendix table 11) (Adam and Anderson, 1992). The average cost per bushel for cleaning the same wheat at subterminal elevators was 3.8 cents (Adam and Anderson, 1992). The primary reason the cost was much lower at subterminal elevators was their ability to use higher capacity cleaners more efficiently. This reduced fixed costs to 0.6 cents per bushel and average variable costs to 3.2 cents per bushel. The substantially lower costs suggest that subterminal elevators are generally able to take advantage of economies of scale for cleaning. The total annual cost of cleaning all winter wheat for export (719 million bushels) at subterminal elevators is $27 million, $21 million less than the cost of cleaning the same wheat at country elevators.

A comparison of the total cost of cleaning at country versus subterminal elevators reveals that the largest economies of scale come from reduced annual capital expenditures. The variable costs also show economies of scale but the investment can be reduced and annual cost lowered. These savings accrue because fewer cleaners are required. The engineering study reveals that by locating cleaners at subterminal elevators, the capital necessary is reduced and the cleaners can be run less expensively. The total cost of cleaning wheat increases as the quantity cleaned increases (appendix table 12). The total annual cost of cleaning all nonfeed wheat (1.15 billion bushels) at country elevators is $68 million and $41 million at subterminal elevators. This is $20 million and $14 million more than the cost of cleaning all winter wheat for export. Reduced variable costs account for most of the difference because the smaller volume cleaned reduces the time the cleaner must be operated. Fixed costs are lower but the reduction is not as significant because the study assumes each country elevator cleans some wheat and therefore requires grain-cleaning equipment. Savings only occur when less equipment is needed.

The engineering analysis found that, as the amount of wheat to be cleaned increased, the cost per bushel cleaned decreased. The average total cost per bushel for cleaning all nonfeed wheat was estimated to be 5.9 cents at country elevators and 3.6 cents at subterminal elevators (appendix tables 13 and 14) (Adam and Anderson, 1992). Both the variable cost and fixed cost of cleaning a bushel of wheat declined at country and subterminal elevators. The results for these scenarios also suggest that economies of scale are an important consideration for grain-cleaning operations.

A change in the grain standards that lowers the wheat dockage content would have regional effects. These regional effects would occur because: (1) elevators in

Appendix table 11--Per bushel costs, benefits, and net benefits from cleaning winter wheat, 1990-91

Item	Fixed costs	Variable costs	Total costs	Benefits	Net benefits
			Cents/bushel		
Cleaning winter wheat for export:					
Country elevator	2.4	4.3	6.7	3.0	-3.7
Subterminal	.6	3.2	3.8	2.2	-1.6
Cleaning nonfeed winter wheat:					
Country elevator	1.8	4.1	5.9	2.9	-3.0
Subterminal elevator	.6	3.0	3.6	2.1	-1.5

Source: Adam and Anderson, 1992.

Appendix table 12--Aggregate costs, benefits, and net benefits from cleaning winter wheat, 1990-91

Item	Fixed costs	Variable costs	Total costs	Benefits	Net benefits
			Million dollars		
Cleaning winter wheat for export:					
Country elevator	17.4	31.1	48.2	21.5	-26.6
Subterminal	4.3	23.0	27.3	15.8	-11.5
Cleaning all nonfeed winter wheat:					
Country elevator	20.6	47.0	67.7	33.3	-34.4
Subterminal	6.9	34.4	41.3	24.1	-17.2

Source: Adam and Anderson, 1992.

different regions currently do not have the same grain-cleaning capacity, (2) production and harvesting practices differ across regions, and (3) biological considerations, such as class of wheat grown, weeds, and insects, differ. Adam and Anderson (1992) estimated the cost of cleaning wheat for each State. Their analysis showed considerable variability in the per bushel cost of cleaning wheat (appendix tables 13-16). The highest cost States under all scenarios invariably had the highest fixed costs, while the lowest cost elevators all had very low fixed costs. This result reflects both the importance of economies of scale in cleaning and the effect of different types of dockage on regional cleaning costs.[15]

The cleaning costs by State can be used to examine the influence wheat class can have on costs. The cleaning cost at country elevators in the three top HRW-producing States ranged from 5.3 to 6.0 cents per bushel. The cleaning costs for the top five SRW States ranged from 6.4 to 12.2 cents per bushel. These results reflect the fact that SRW production is less concentrated than HRW and country elevators in these States handle less wheat on average. Both of these factors increase the cost of cleaning SRW. However, when the cleaning occurred at subterminal elevators, the differences in costs between HRW and SRW wheat States disappeared, suggesting that cleaning at subterminal elevators permits similar economies of scale for HRW and SRW. These results suggest that if a low-dockage policy were adopted, care should be taken to permit elevators to take advantage of economies of scale.

The NGFA survey data provides information on the variable costs of cleaning wheat by class and region. The elevator operators responding to the survey indicate an average cost of reducing dockage by 0.5 percentage points for HRW of 4.3 cents per bushel (appendix table 17), which is similar to the variable costs found in the economic engineering study (appendix tables 13-16).

The average cleaning cost for SRW elevators was 6.4 cents per bushel (appendix table 17), somewhat higher than the estimated variable costs from the engineering study (appendix tables 13-16). Because the costs from the survey exclude the cost of wheat lost during cleaning, the actual average cleaning costs implied by the survey are somewhat higher than the cost estimated in the engineering study. However, the variability associated with the costs from the commercial elevators was such that the costs are not statistically different from the engineering costs.

Benefits of Cleaning Winter Wheat

Engineering analysis of cleaning winter wheat indicates that while savings accrue from lowering the costs associated with insects and aeration, the largest benefits associated with cleaning result from the sale of the screenings and the reduction in transportation costs.[16] Adam and Anderson estimated that screenings sales can account for up to 70 percent of the benefits from cleaning wheat. Savings from reduced transportation expenditures can account for another 20 to 40 percent, while savings from lower fumigation costs and reduced insect losses were estimated to cover approximately 10 percent of the benefits.

Adam and Anderson report that the revenues from selling wheat cleanings are between 1.3 and 1.9 cents per bushel. This is higher than the average of 0.3 cents per bushel reported by commercial elevators (NGFA, 1991).

[15]One reason for the wide range in the costs between elevators in different States is the assumption that each elevator cleans wheat and therefore requires cleaning equipment. If wheat production is concentrated in one portion of a State, this would not hold and the fixed costs would be exaggerated. This likely explains the high cleaning costs in Iowa.

[16]The engineering analysis does not address the potential benefits that might occur if cleaning resulted in an increased U.S. share of international wheat markets. The trade effects of cleaning U.S. wheat are discussed elsewhere in the report. The engineering study did not examine potential benefits from health, environmental, or dust control aspects of wheat cleaning.

Appendix table 13--All nonfeed winter wheat cleaned, country elevators

State	Benefit	Fixed cost	Variable cost	Total cost	Net benefit
			Cents/bushel		
Alabama	3.2	2.6	4.1	6.7	-3.5
Arizona	3.2	10.9	3.9	14.8	-11.6
Arkansas	2.3	3.4	2.7	6.1	-3.8
California	2.3	1.4	2.8	4.2	-1.9
Colorado	2.3	0.7	2.5	3.2	-.9
Delaware	3.1	10.4	4.2	14.6	-11.5
Florida	3.3	10.4	3.7	14.1	-10.8
Georgia	3.2	1.3	4.0	5.3	-2.1
Idaho	2.3	.4	2.6	3.0	-.7
Illinois	2.4	5.1	4.7	9.8	-7.4
Indiana	2.4	4.4	6.4	10.8	-8.4
Iowa	2.4	36.6	4.7	41.3	-38.9
Kansas	3.2	.6	4.3	4.9	-1.7
Kentucky	3.2	3.0	4.2	7.2	-4.0
Louisiana	3.1	1.0	4.4	5.4	-2.3
Maryland	3.1	0	4.3	4.3	-1.2
Michigan	3.1	0	4.3	4.3	-1.2
Minnesota	3.1	0	4.3	4.3	-1.2
Mississippi	2.4	4.4	4.4	8.8	-6.4
Missouri	3.2	3.8	4.1	7.9	-4.7
Montana	2.3	3.2	2.6	5.8	-3.5
Nebraska	3.2	.4	4.2	4.6	-1.4
New Jersey	3.1	10.4	4.3	14.7	-11.6
New Mexico	3.2	.5	4.2	4.7	- 1.5
New York	3.1	0	4.2	4.2	- 1.1
North Carolina	2.3	8.4	2.4	10.8	-8.5
North Dakota	3.1	0	4.1	4.1	-1.0
Ohio	2.3	0	6.7	6.7	-4.4
Oklahoma	3.2	.6	4.3	4.9	-1.7
Oregon	3.1	0	4.6	4.6	-1.5
Pennsylvania	3.1	10.4	4.5	14.9	-11.8
South Carolina	3.1	1.8	4.1	5.9	-2.8
South Dakota	3.2	0	4.1	4.1	-.9
Tennessee	3.2	1.9	4.2	6.1	-2.9
Texas	3.2	.8	4.3	5.1	-1.9
Utah	3.2	10.9	4.3	15.2	-12.0
Virginia	3.1	1.3	4.2	5.5	-2.4
Washington	2.3	.9	2.9	3.8	-1.5
West Virginia	3.1	10.4	4.3	14.7	-11.6
Wisconsin	3.2	0	4.1	4.1	-.9
Wyoming	3.1	10.9	4.1	15.0	-11.9
United States	2.9	1.8	4.1	5.9	-3.0

Source: Adam and Anderson, 1992.

Appendix table 14--All nonfeed winter wheat cleaned, subterminal elevators

State	Benefit	Fixed cost	Variable cost	Total cost	Net benefit
			Cents/bushel		
Alabama	2.0	0.5	2.7	3.2	-1.2
Arizona	2.8	1.1	4.3	5.4	-2.6
Arkansas	2.0	.4	2.9	3.3	-1.3
California	2.0	.2	2.9	3.1	-1.1
Colorado	2.0	.8	2.8	3.6	-1.6
Delaware	2.8	1.0	4.6	5.6	-2.8
Florida	2.9	1.0	4.0	5.0	-2.1
Georgia	2.8	.3	4.4	4.7	-1.9
Idaho	2.0	.3	2.8	3.1	-1.1
Illinois	2.0	1.6	2.8	4.4	-2.4
Indiana	2.0	.5	2.8	3.3	-1.3
Iowa	2.1	7.2	4.9	12.1	-10.0
Kansas	2.0	.5	2.8	3.3	-1.3
Kentucky	2.8	.4	4.6	5.0	-2.2
Louisiana	2.8	6.0	4.8	10.8	-8.0
Maryland	2.8	0	4.6	4.6	-1.8
Michigan	2.8	0	4.6	4.6	-1.8
Minnesota	2.8	0	4.6	4.6	-1.8
Mississippi	2.0	.7	2.8	3.5	-1.5
Missouri	2.0	.4	2.7	3.1	-1.1
Montana	2.0	.3	2.8	3.1	-1.1
Nebraska	2.0	.2	2.7	2.9	-.9
New Jersey	2.8	1.0	4.7	5.7	-2.9
New Mexico	2.0	.3	2.7	3.0	-1.0
New York	2.8	0	4.5	4.5	-1.7
North Carolina	2.0	1.4	2.6	4.0	-2.0
North Dakota	2.0	0	2.6	2.6	-.6
Ohio	2.0	0	2.9	2.9	-.9
Oklahoma	2.0	.4	2.8	3.2	-1.2
Oregon	2.8	0	5.0	5.0	-2.2
Pennsylvania	2.8	1.0	4.8	5.8	-3.0
South Carolina	2.0	1.4	2.6	4.0	-2.0
South Dakota	2.0	0	2.7	2.7	-.7
Tennessee	2.8	.5	4.5	5.0	-2.2
Texas	2.0	.6	2.8	3.4	-1.4
Utah	2.8	1.1	4.6	5.7	-2.9
Virginia	2.0	.3	2.7	3.0	-1.0
Washington	2.0	.5	3.1	3.6	-1.6
West Virginia	2.8	1.0	4.7	5.7	-2.9
Wisconsin	2.8	0	4.5	4.5	-1.7
Wyoming	2.8	1.1	4.5	5.6	-2.8
United States	2.1	.6	3.0	3.6	-1.5

Source: Adam and Anderson, 1992

Appendix table 15--All export winter wheat cleaned, country elevators

State	Benefit	Fixed cost	Variable cost	Total cost	Net benefit
			Cents/bushel		
Alabama	3.2	4.2	4.1	8.3	-5.1
Arizona	3.2	17.3	3.9	21.2	-18.0
Arkansas	2.3	5.3	2.7	8.0	-5.7
California	2.3	2.3	2.8	5.1	-2.8
Colorado	3.2	0.3	4.2	4.5	-1.3
Delaware	3.1	16.8	4.2	21.0	-17.9
Florida	3.3	16.8	3.7	20.5	-17.2
Georgia	3.2	0	4.0	4.0	-.8
Idaho	2.3	0.7	2.6	3.3	-1.0
Illinois	2.4	8.0	4.7	12.7	-10.3
Indiana	2.4	5.8	6.4	12.2	-9.8
Iowa	2.4	58.4	4.7	63.1	-60.7
Kansas	3.2	.9	4.3	5.2	-2.0
Kentucky	3.2	4.8	4.2	9.0	-5.8
Louisiana	3.1	1.4	4.4	5.8	-2.7
Maryland	3.1	0	4.3	4.3	-1.2
Michigan	3.1	0	4.3	4.3	-1.2
Minnesota	3.1	0	4.3	4.3	-1.2
Mississippi	2.4	7.1	4.4	11.5	-9.1
Missouri	3.2	6.0	4.1	10.1	-6.9
Montana	2.4	2.5	4.8	7.3	-4.9
Nebraska	3.2	0	4.2	4.2	-1.0
New Jersey	3.1	16.8	4.3	21.1	-18.0
New Mexico	3.2	0.3	4.2	4.5	-1.3
New York	3.1	0	4.2	4.2	-1.1
North Carolina	2.3	8.8	5.5	14.3	-12.0
North Dakota	3.1	0	4.1	4.1	-1.0
Ohio	2.3	0	6.7	6.7	-4.4
Oklahoma	3.2	.7	4.3	5.0	-1.8
Oregon	3.1	0	4.6	4.6	-1.5
Pennsylvania	3.1	16.8	4.5	21.3	-18.2
South Carolina	3.1	2.9	4.1	7.0	-3.9
South Dakota	3.2	0	4.1	4.1	-.9
Tennessee	3.2	3.1	4.2	7.3	-4.1
Texas	3.2	1.0	4.3	5.3	-2.1
Utah	3.2	17.3	4.3	21.6	-18.4
Virginia	3.1	2.1	4.2	6.3	-3.2
Washington	3.1	.3	4.7	5.0	-1.9
West Virginia	3.1	16.8	4.3	21.1	-18.0
Wisconsin	3.2	0	4.1	4.1	-.9
Wyoming	3.1	17.3	4.1	21.4	-18.3
United States	3.0	2.4	4.3	6.7	-3.7

Source: Adam and Anderson, 1992.

Appendix table 16--All export winter wheat cleaned, subterminal elevators

State	Benefit	Fixed cost	Variable cost	Total cost	Net benefit
			Cents/bushel		
Alabama	2.0	0.7	2.7	3.4	-1.4
Arizona	2.8	1.7	4.3	6.0	-3.2
Arkansas	2.0	.7	2.9	3.6	-1.6
California	2.0	.4	2.9	3.3	-1.3
Colorado	2.8	.3	4.5	4.8	-2.0
Delaware	2.8	1.7	4.6	6.3	-3.5
Florida	2.9	1.7	4.0	5.7	-2.8
Georgia	2.8	0	4.4	4.4	-1.6
Idaho	2.0	.3	2.8	3.1	-1.1
Illinois	2.1	1.3	4.0	5.3	-3.2
Indiana	2.0	.6	2.8	3.4	-1.4
Iowa	2.1	11.5	4.9	16.4	-14.3
Kansas	2.0	.5	2.8	3.3	-1.3
Kentucky	2.8	.6	4.6	5.2	-2.4
Louisiana	2.8	8.9	4.8	13.7	-10.9
Maryland	2.8	0	4.6	4.6	-1.8
Michigan	2.8	0	4.6	4.6	-1.8
Minnesota	2.8	0	4.6	4.6	-1.8
Mississippi	2.0	1.1	2.8	3.9	-1.9
Missouri	2.0	.7	2.7	3.4	-1.4
Montana	2.0	.4	2.8	3.2	-1.2
Nebraska	2.8	0	2.7	2.7	-0.1
New Jersey	2.8	1.7	4.7	6.4	-3.6
New Mexico	2.0	.2	2.7	2.9	-.9
New York	2.8	0	4.5	4.5	-1.7
North Carolina	2.0	2.2	2.6	4.8	-2.8
North Dakota	2.0	0	2.6	2.6	-.6
Ohio	2.0	0	2.9	2.9	-.9
Oklahoma	2.0	.4	2.8	3.2	-1.2
Oregon	2.8	0	5.0	5.0	-2.2
Pennsylvania	2.8	1.7	4.8	6.5	-3.7
South Carolina	2.8	.8	4.4	5.2	-2.4
South Dakota	2.0	0	2.7	2.7	-.7
Tennessee	2.8	.8	4.5	5.3	-2.5
Texas	2.0	.7	2.8	3.5	-1.5
Utah	2.8	1.7	4.6	6.3	-3.5
Virginia	2.0	.4	2.7	3.1	-1.1
Washington	2.0	.7	3.1	3.8	-1.8
West Virginia	2.8	1.7	4.7	6.4	-3.6
Wisconsin	2.8	0	4.5	4.5	-1.7
Wyoming	2.8	1.7	4.5	6.2	-3.4
United States	2.2	.6	3.2	3.8	-1.6

Source: Adam and Anderson, 1992

Appendix table 17--Cost of reducing dockage in hard red winter and soft red winter wheat

Region	Dockage removed	Cost of cleaning	Cost of reducing dockage 0.5 percent
	Percent	*Cents/bushel*	*Cents/bushel*
Hard red winter:			
Northern Plains	0.89	4.40	4.57
Southern Plains	.84	5.95	3.36
National average	.87	4.55	4.34
Soft red winter:			
National average	.59	10.14	6.42

Source: NGFA, 1991, commercial elevator survey.

Among the reasons for this are the costs associated with marketing and transporting the screenings. Because the market for wheat cleanings is thin and increased cleaning activity would likely cause screenings prices to decline, the revenues estimated by Adam and Anderson might be considered the upper bound.

Net Benefits from Cleaning Wheat

The costs of cleaning winter wheat exceed the domestic benefits, resulting in a net cost (negative net benefits) that must be borne by the industry. It can be assumed that the wheat industry would respond to a change in cleanliness requirements by adopting the most efficient means to clean wheat. This suggests that $11.5 million in net losses must be distributed between farmers, millers, elevator operators, and importers of U.S. wheat. It is difficult to determine now which sector within the industry will bear this cost. However, it can be stated with some confidence that flour millers are unlikely to share much of the burden because they are risk averse, have the equipment in place, and will clean all wheat milled no matter what level of dockage it contains.

The net costs are a function of the point of cleaning and quantity of wheat to be cleaned. The location of the cleaning operation is the more important factor because grain cleaning exhibits economies of scale. Net domestic benefits from cleaning winter wheat are maximized (costs minimized) when the cleaners are located at subterminal elevators rather than country elevators. The lower net costs stem from the reduced capital requirements and operating costs at subterminal elevators; more than offsetting the marginally lower benefit from transportation savings.

The net domestic benefits per bushel cleaned were not observed to exceed the costs. This holds under all scenarios, although the per unit costs declined as the volume cleaned increased. Thus, the more wheat cleaned, the greater the total net cost. Because a larger volume is cleaned, cleaning all nonfeed winter wheat results in a higher aggregate net loss than cleaning only the winter wheat exported. Most of the higher net cost results from larger operating costs, although some additional capital expenditures are required.

Appendix C: Spring Wheat

Wheat of different classes has different physical and intrinsic quality characteristics. The differences in these characteristics are due to different harvesting and production practices, growing conditions, and genetic traits, that can affect wheat cleanliness and wheat-cleaning costs. This appendix examines the costs and benefits of cleaning spring wheat.

Market Discounts and Premiums

Commercial elevators that handle spring wheat use market discounts, premiums, and weight deductions when purchasing spring wheat. The amount of dockage and foreign material (FM) in spring wheat varies by class, location, and year (appendix tables 18-20). For this reason the discounts, premiums, and deductions on dockage and FM also vary.

Ninety-seven percent of elevators handling spring wheat in North and South Dakota deducted the weight of dockage. In addition to weight deductions, 72 percent of elevators handling spring wheat had price discounts at 3-

Appendix table 18--Spring wheat: Weighted average dockage and foreign material, by operation

Location	Dockage	Foreign material
	Percent	
Country	1.83	0.51
Inland terminal	.50	.30
Export	.90	.70
All elevators	1.59	.49

Source: NGFA, 1991, commercial elevator survey.

percent dockage or less, and 54 percent had discounts at 1-percent or less. The proportion of spring wheat elevators that levied price discounts at high dockage levels rises much faster than winter wheat elevators. Fewer than 1 percent of the elevators were offered premiums for low-dockage wheat.

Unlike dockage that is discounted with a combination of price and weight, elevators mainly discount foreign material by price. Elevators usually start discounts at the U.S. No. 2 grade limit for FM, which is 0.6-1.0 percent. Minnesota and Montana elevators charged the highest discounts in the spring wheat-producing States. The discounts charged for FM are progressive (appendix table 21).

Wheat Cleaning

Nearly all elevators in the Dakotas and Minnesota that handle hard red spring (HRS) wheat and durum have cleaning equipment and clean some amount when necessary. The cleaning cost varies with the amount and type of dockage that is removed. The type of dockage varies from one State to another. Appendix table 22 presents the cost of cleaning by State and amount removed.

Country Elevators

The estimates in appendix table 23 assume that an amount equivalent to HRS and durum wheat exports are cleaned from 3-percent dockage to 0.4-percent dockage at country elevators. This level is equivalent to the cleanliness of Canadian spring wheat exports. This reduction is more appropriate for a high-dockage year like 1987 but overstates the magnitude of the dockage problem in most years. The average dockage received by country elevators is 1.83 percent (appendix table 19). The analysis also assumes that the required cleaning capacity is available, which is tenable because over 90 percent of elevators in North Dakota, South Dakota, and Minnesota already have cleaners. So, the additional cost to clean is the cost difference between the current ending dockage (about 0.7 percent) to 0.4 percent. The aggregate additional cost of duplicating the Canadian standard would be at least $3.4 million a year for 1987 but as much as $11 million in 1990, a low-dockage year.

Export Elevators

Appendix table 24 assumes a reduction in dockage from 1.0 percent to 0.4 percent rather than the 3.0 percent beginning dockage in appendix table 23. It was felt this level more accurately reflected the actual beginning dockage arriving at the export elevator. The estimates in appendix table 24 also assume that all export elevators can be retrofitted to install or increase cleaning capacity to clean all exports. The estimates should be considered conservative as 62 percent of export elevators responding to the NGFA survey said that cleaners could not be installed in the current space. The estimated cost is also based on an assumption that installation cost is equal to equipment cost; however, port elevators may require much additional expense in installing cleaners. For port elevators, cleaning all wheat exports would require building additional structures at considerable expense. The lack of land space or the technical problems of altering the current elevator configuration may be overwhelming. Nonetheless, the aggregate additional cost of cleaning HRS and durum wheat at export elevators would be at least $10-$12 million each year. Cleaning white wheat would add about $8-$11 million.

The analysis in appendix table 24 does not evaluate the additional cost of matching cleaning capacity to loadout capacity. The per unit cost is based on a single cleaner with a 20,000-bushel-per-hour capacity, operated for 700 hours, for a total throughput of 7 million bushels each year. Some export elevators handle much more wheat than 7 million bushels. A previous cost study (Fridirici and others, 1984) estimated that the annual cost of cleaning at a typical port elevator that maintained cleaning capacity equal to throughput capacity was $11 million, or 13.7 cents per bushel. Even this estimate was conservative as it did not include such costs as new housing for cleaners, a reclaim system for wheat loss, additional ducts and legs, or land acquisition costs.

Cleaning all wheat exports would require substantial new investment in capacity or a severe constraint on current throughput volume. Elevators with cleaners had hourly operating capacities averaging 42 percent of their total hourly loadout capacity. However, further reducing the target dockage level to 0.5 percent would reduce working capacity to about one-fourth of the loadout capacity. Export contracts often reward fast loading of vessels by offering premiums or by charging demurrage for delays.

Appendix table 19--Hard red spring wheat, average foreign material and dockage by State, 1987-90

States	Foreign material				Dockage			
	1987	1988	1989	1990	1987	1988	1989	1990
	Percent							
California	0.36	0.65	0.2	0.59	NA	NA	NA	NA
Colorado	NA	NA	NA	NA	NA	NA	NA	0.7
Idaho	.45	NA	.45	.74	.97	1.07	1.06	.85
Iowa	.1	.71	.1	NA	1.01	NA	.7	NA
Kansas	NA	.34	NA	NA	NA	NA	NA	NA
Minnesota	.27	NA	.2	.15	1.5	1.14	.88	.86
Montana	.24	.22	.29	.53	.83	1.7	.98	1.07
Nebraska	.16	NA	.05	NA	1.08	NA	.55	NA
North Dakota	.34	.66	.25	.21	1.09	1.3	.78	.57
Oregon	NA	.26	NA	0	NA	NA	NA	.2
South Dakota	NA	NA	NA	.37	NA	NA	NA	1.4
Utah	.49	.89	.78	.28	1.23	1.48	.65	.85
Washington	.07	.1	.22	.06	.69	.71	.57	.72
Wisconsin	.19	.22	.23	.17	1.3	1.02	.73	.78
National	.19	.21	.23	.16	1.09	1.03	.76	.73

NA = Not available.
Source: NGFA, 1991, commercial elevator survey.

Appendix table 20--Durum wheat, average foreign material and dockage by State, 1987-90

States	Foreign material				Dockage			
	1987	1988	1989	1990	1987	1988	1989	1990
	Percent							
California	0.47	0.43	0.55	0.44	1.03	0.88	1.35	0.96
Idaho	NA	NA	.92	NA	NA	1.35	2.06	4.3
Minnesota	.76	.39	.32	.27	1.42	.73	.65	.65
Montana	NA	NA	1.32	.09	NA	NA	.92	.93
North Dakota	.31	.21	.3	.29	1.14	1.08	.87	.66
Oregon	NA	NA	.63	NA	NA	NA	3.1	NA
Utah	NA	NA	.37	.53	.76	.72	.75	.61
Washington	NA	NA	.2	.1	NA	NA	.6	1.8
Wisconsin	.47	NA	.37	.43	1.84	NA	.95	.66
National	.42	.35	.47	.38	1.08	.92	1.24	.84

NA=Not available.
Source: Commercial elevator survey, NGFA, 1991.

Appendix table 21--Spring wheat: Weighted average foreign material discounts by State

Foreign material discount	Minnesota	South Dakota	North Dakota	Montana	All States
Percent of FM discount			*Cents/bushel*		
0.5-1.0	0.01	0	0.03	0.12	0.02
1.0-1.5	1.22	.97	.96	1.37	.95
1.5-2.0	2.32	2.79	2.30	3.41	2.33
2.0-2.5	4.02	4.66	3.30	5.53	3.75
2.5-3.0	5.49	6.44	3.96	7.64	4.96
3.0 and over	6.66	10.77	5.14	8.55	7.57

Source: NGFA, 1991, commercial elevator survey.

Appendix table 22--Spring wheat weighted average cleaning costs, by State

State	Cleaning costs by percentage point reduction				
	0-0.5 percent	0.5-1.0 percent	1.0-1.5 percent	1.5-2.0 percent	Over 2 percent
			Cents/bushel		
Minnesota	3.81	5.17	4.35	5.00	6.31
South Dakota	3.40	3.40	3.46	3.54	3.62
Montana	3.86	4.50	5.68	6.64	8.36
North Dakota	3.80	4.13	6.07	6.34	6.32
All States	3.64	4.06	4.70	5.00	5.44

Source: NGFA, 1991, commercial elevator survey.

Slowing the throughput rate would jeopardize U.S. competitiveness as a reliable supplier. A considerable amount of precleaning (upon receipt rather than loadout) would be necessary to avoid a slowdown of loadout capacity at export. These costs are not quantified in the analysis.

Aggregate Net Cost

About 76 percent of Canadian western red spring (CWRS) exported is in the top two grades. CWRS No. 1 and No. 2 have limits of 0.4 and 0.75 percent on dockage, foreign material, and broken kernels combined (as defined in the U.S. wheat standards). Most of the CWRS being exported has a lower dockage level than is required. The average dockage level is around 0.2 percent. Less than 5 percent of U.S. HRS and durum exports would currently meet the No. 1 Canadian grade.

Over the last 10 years, the United States exported an average of 480 million bushels per year of HRS, durum, and white wheat. Average total stocks over this period were 546 million bushels. The net cost of cleaning all spring wheat exports to 0.4 percent dockage would average approximately 2.8 cents per bushel or $13.6 million each year, in aggregate. This analysis assumes that the incoming dockage level at export elevators will average 1.0 percent (which presumes that inland elevators would continue their current cleaning practices).

Appendix table 23--Aggregate costs of cleaning HRS and durum wheat exports at country elevators, 1987

Item	Cleaning costs per bushel[1]	Aggregate costs[1]	Cleaning costs per bushel[2]	Aggregate costs[2]	Additional cost
	Cents/bushel	*Million dollars*	*Cents/bushel*	*Million dollars*	*Million dollars*
Depreciation:					
Cleaner	0.66	2.1	0.66	2.1	0
Installation	.66	2.1	.66	2.1	0
Opportunity costs of capital:					
Cleaner	.90	2.9	1.10	3.5	.6
Installation	.90	2.9	1.10	3.5	.6
Total fixed costs	3.00	9.5	3.52	11.2	1.7
Wheat loss	.51	1.6	.95	3.0	1.4
Energy	.54	1.7	.54	1.7	0
Labor	.40	1.3	.51	1.6	.3
Maintenance	.09	.3	.09	.3	0
Total variable	1.54	4.9	2.09	6.6	1.7
Total cost	4.54	14.4	5.61	17.8	3.4

[1]Based on the following assumptions: Country elevators clean all spring wheat destined for export (480-million-bushel average), use 500 bu/hr disc-cylinder cleaner, installation cost equals cleaner cost, 13.3 percent interest, straight-line depreciation over 25-year useful life, cleaning from 3.0-percent dockage down to 0.4 percent, 0.7-percent wheat loss.

Appendix table 24--Aggregate costs of cleaning HRS and durum wheat exports at export elevators

Item	Cleaning costs per bushel[1]	Aggregate cost[1]
	Cents/bushel	*Million dollars*
Depreciation:		
Cleaner	.10	0.3
Installation	.10	.3
Opportunity costs of capital:		
Cleaner	.17	.5
Installation	.17	.5
Total fixed costs	.53	1.7
Wheat loss	2.28	7.2
Energy	.03	.1
Labor	.88	2.8
Maintenance	.01	.1
Total variable	3.19	10.1
Total cost	3.73	11.8

[1]Based on the following assumptions: Export elevators clean all 317-million-bushel average spring wheat exports, use 20,000 bu/hr screen cleaner for 700 hours, installation cost equals cleaner cost, 13.3 percent interest, straight-line depreciation over 25-year useful life, cleaning from 1.0-percent dockage down to 0.4 percent, 0.7-percent wheat loss.

The NDSU study did a cost-benefits analysis of cleaning HRS, durum, and white wheat in 2 crop years, 1987, representing the high-dockage year, and 1990, representing the low-dockage year. No analysis was conducted for white wheat in 1990. The analysis began with a cost and benefits of cleaning in each year under approximately original conditions; that is, all wheat is cleaned to 0.7-percent dockage. Then, simulations were conducted to measure the change in net cleaning costs given different circumstances. The cases are: (1) the entire HRS wheat, durum, and white wheat production is required to meet a specific dockage level, 0.5 or 0.2 percent, and (2) only HRS, durum, and white wheat exports need meet the dockage limit.

In 1987 (a high-dockage year), the net cost ranged from \$12.9 million for HRS and \$5.0 million for durum. A policy restricting dockage to 0.5 percent in 1987 would have increased the net cost to \$14.6 million and \$5.6 million for HRS and durum, respectively. Alternatively, by requiring all exports to have 0.5-percent dockage would result in net costs of \$13.9 million and \$5.4 million for HRS and durum, respectively. Thus, the added cost of cleaning all spring wheat to 0.5 percent dockage in 1987 would be about \$3 million. This estimate is lower than the preceding table because the NDSU study also permits both the country or export elevator to clean, whichever is most efficient, and allows for blending to meet the dockage limit.

Original net costs would have been smaller in the low-dockage year, 1990. However, by restricting dockage to 0.5 percent the net costs for that year would have increased by \$4.9 million, \$1.1 million, and \$0.9 million for HRS, durum, and white wheat, respectively. Alternatively, requiring all exports to have 0.5-percent dockage would result in higher net costs of \$1.9 million for HRS, \$0.4 million for durum, and \$0.7 million for white wheat.

Further reducing the dockage level to 0.2 percent (which would match the level of cleanliness in Canadian wheat) would increase net costs in 1987 (a high-dockage crop year) by \$5 million and \$2 million for HRS and durum, respectively. Cleaning only exports to this level would change the net costs in 1987 by \$3 million for HRS and \$2 million for durum. In 1990 (a low-dockage crop year), additional net costs of cleaning wheat under the same scenario would have been \$12 million, \$3 million, and \$2 million for HRS, durum, and white wheat, respectively. Cleaning only exports to this level would change the net costs in 1990 by \$4 million for HRS, \$1 million for durum, and \$2 million for white wheat.

In summary, policies to reduce dockage in spring-grown and white wheats would increase the cost to elevators and farmers (excluding the potential benefit from export expansion) from \$11 million to \$20 million each year, depending on the crop's original cleanliness and the dockage limit.

Appendix D: Farm Cleaning Simulation

Wheat producers rated avoiding discounts and improving storability as their major reasons for cleaning. Without an explicit discount for dockage, farmers have little incentive to clean wheat, due to the loss of grain during an additional handling and the minimal reduction in storage losses. Larger farms would have the volume to spread the fixed costs because grain cleaners could also be used for other grains. Having cattle on the farm would also help capture the benefit of feeding the screenings to livestock owned by the farm (although these farms also have the option of feeding high-dockage grain without cleaning it). Survey results indicate that farmers that owned cleaners had 15-20 percent higher wheat production, on average, than those that did not.

Farm-type cleaners reduce dockage and shrunken and broken kernels. Cleaning wheat onfarm would likely reduce foreign material (FM) and damaged kernels and increase test weight only slightly. The base scenario assumes that the farmer cleans wheat to meet U.S. No. 1 limits (including an assumed limit of 0.5-percent dockage). A schedule of discounts for current grade factors are assumed for valuing the improved cleanliness. Although the discounts frequently vary over time and by location, the assumed discounts approximate recent observations. The initial shrunken and broken kernel percentage is allowed to vary with the dockage level. The reduction in shrunken and broken kernels is based on a formula estimated by Kiser and Duncan (1991).

The analysis is based on the purchase price, operating capacity, and other specifications of a current farm-type grain cleaner. The cleaning capacity varies between 975, 1,075, and 1,150 bushels per hour, depending on the beginning dockage level. The operating cost of the cleaner is assumed to be \$5.00 per-hour, which is multiplied by the total hours used to obtain the total operating cost. The analysis applies the interest cost for the first year of use. This assumption is pertinent because a cleaner may cover operating costs under certain conditions but the payback period for the ownership cost may exceed the useful life of the cleaner. Wheat lost through spillage or damaged in the extra handling is assumed to be 1.0 percent. This value appears to have the greatest impact on the operating costs of the cleaner.

Appendix table 25--Quantity and shipping assumptions

Item	Unit	Not cleaned	Cleaned
Handled	Pounds	1,000,000	
Removed	Percent	0	1.1
Handling loss	Percent	0	1.0
Cleanings	Pounds	0	10,573
Cleanings price	Dollar/ton	NA	$30
Ending dockage	Percent	1.5	.5
Net sold	Pounds	985,000	974,530
Net sold	Bushels	16,417	16,242
Market price	Dollar/bushel	$3.00	$3.00

NA = Not applicable.

Appendix table 26--Grading factor assumptions

Item	Unit	Not cleaning	Discount (cents/bushel)	Cleaning	Discount (cents/bushel)
Test weight	Pounds	60.1	0	60.3	0
Damaged kernels	Percent	.8	0	.8	0
Foreign material	Percent	.2	0	.1	0
Shrunken and brokens	Percent	1.1	0	1.0	0
Total defects	Percent	2.1	0	1.9	0
Total discount	Cents/bushel		0		0
Net price received	Dollars		$3.00		$3.00

Appendix table 27--Cleaning costs assumptions

Item	Unit	Inputs	Results	Cost
Pounds cleaned per hour	Pounds	58,500		
Hours operated	Hour		17	
Cost per hour	Dollars	5.00		
Operation cost	Dollars			85.47
Equipment life	Years	20		
Equipment price	Dollars	8,300		
Annual depreciation	Dollars			415.00
Annual interest rate	Percent	10.0		
Term of loan	Years	3		
Total interest cost	Dollars		2,490	
Annual interest cost	Dollars			830.00
Total annual cleaning cost	Dollars			1,330.47
Cleaning benefits	Per bushel	0.5		
Total cleaning benefits	Dollars		81.62	

Appendix table 28--Cost-benefits analysis

	Not cleaned	Cleaned
	Dollars	
Value of cleanings	0	158.60
Gross receipts	49,250.00	48,885.09
Net receipts	49,250.00	47,636.24
Cleaning profit (loss) per year		(1,613.76)
Profit (loss) of cleaning per bushel		(0.097)

The base scenario also assumes that farmers, unlike elevators, derive no benefits from reduced transportation or storage space expenses. Virtually all farmers bring grain to market in their own trucks and store unsold grain on the farm. The additional cost to the farmers of transporting dockage to the market or displacing grain in their own bins is practically nil. Farmers seldom fumigate except when an infestation reaches a crisis level, so no reduction in applications is assumed here.[17] An additional cost of handling must also be subtracted from the other storage benefits (lower drying and aeration costs, less insect damage). The net storage benefits are assumed to be 0.5 cent per bushel in the base scenario.

Appendix tables 25-28 present an example of a situation where dockage is reduced from 1.5 percent to 0.5 percent, screenings price is $30 per ton, wheat price is $3 per bushel, and there is no premium for cleaned wheat. Under these conditions, this cleaner would operate at a loss of 9.7 cents per bushel. By varying the levels of particular parameters relative to the base scenario, the sensitivity to each can be mapped out on a chart. The necessary dockage premiums for farmers to cover variable costs given changes in the percentage points of dockage removed, the pounds of wheat handled, the value of screenings, and the wheat price are shown in the accompanying figures.

For instance, appendix figure 6 illustrates that if a farmer does not have livestock or cannot sell the screenings to others, the value of screenings is set to zero. Given this condition, this farmer would need a dockage discount of 10.6 cents to break even.

Appendix figure 7 implies that onfarm cleaning is more feasible when the beginning dockage level is high. Appendix figure 8 suggests that farmers cleaning a greater volume of wheat are better able to lower their per bushel operating cost and achieve a breakeven point sooner. For the base scenario (and a zero discount), the volume cleaned would need to be approximately 325,000 bushels to break even. This amount would be less if dockage were higher than 1.5 percent or screenings prices were greater than $30 per ton.

Thus, wheat farms with less acreage, or having a greater percentage of the crop that is normally below 0.5-percent dockage, or that transport and sell much of the crop directly from the field would have less incentive to invest in a grain cleaner. Factors that increase the cleaning benefits for farm storage (larger stocks, higher energy costs, etc.) would reduce the breakeven price. Higher wheat losses would increase the breakeven price, however (appendix figure 9). For instance, as the wheat price increases from $3 to $4, the cleaning becomes less attractive to the farmer as the value of the wheat lost offsets the benefits.

Based on these calculations, few wheat farms have the conditions that would make cleaning profitable as a standard practice. Only about 10 percent of wheat producers surveyed said they cleaned wheat for market. Farmers would use cleaners if their costs were less than the dockage discount. Most farmers would likely have to bear the discounts as they would not have cleaning costs that were less than the discount. There are currently few price discounts for dockage (in addition to the standard weight deduction). The market discount for dockage under proposed standards would likely approximate the cost of country elevators to clean to the new grade levels. The difference between the dockage discount and the price needed to break even would be the cost imposed on farmers of adding dockage to the grading standards. Alternatively, this per bushel cost would be the price effect necessary from an expansion in wheat exports for the farmer to be as well off as under no change in the grade standards.

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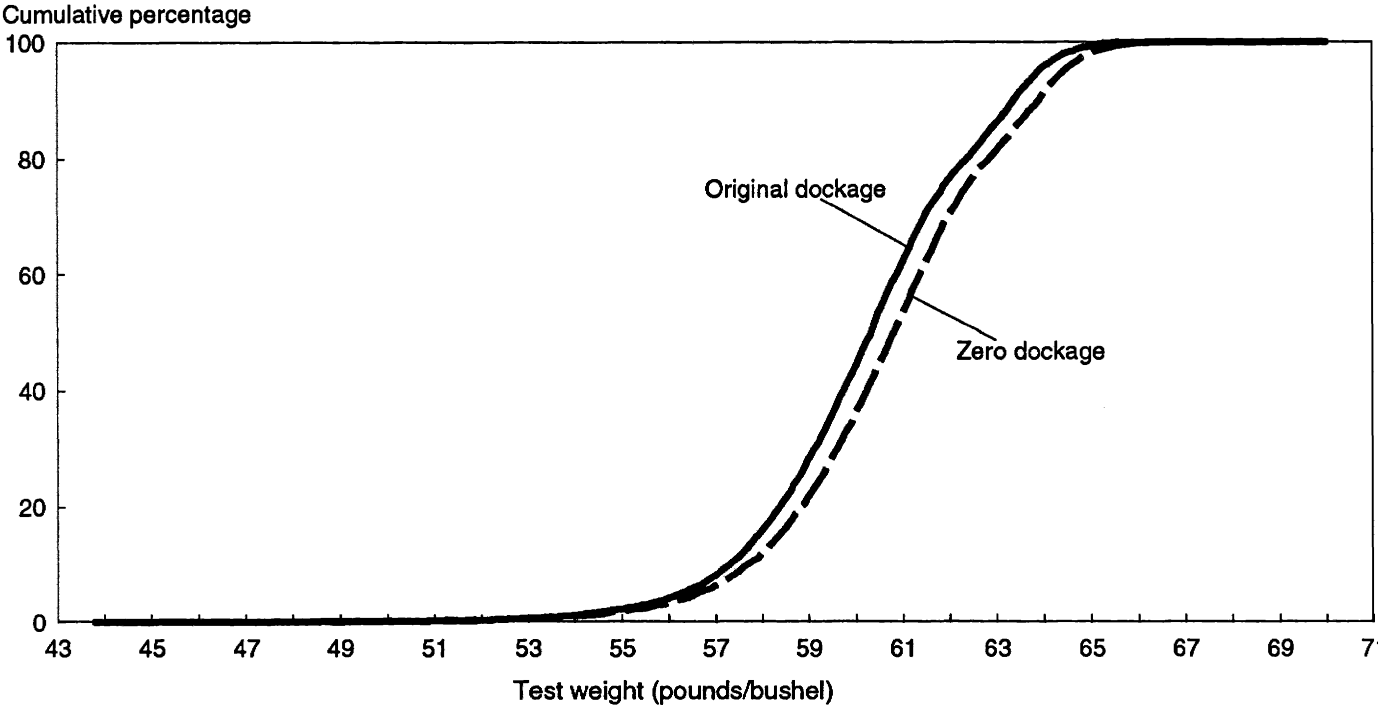
[17]Fumigants are restricted-use chemicals that, by law, require a certified applicator with formal training. One study of farm storage reported that less than 10 percent of wheat was ever fumigated during 1-4 years of storage.

Appendix figure 6

The effect of removing dockage on the test weight of wheat

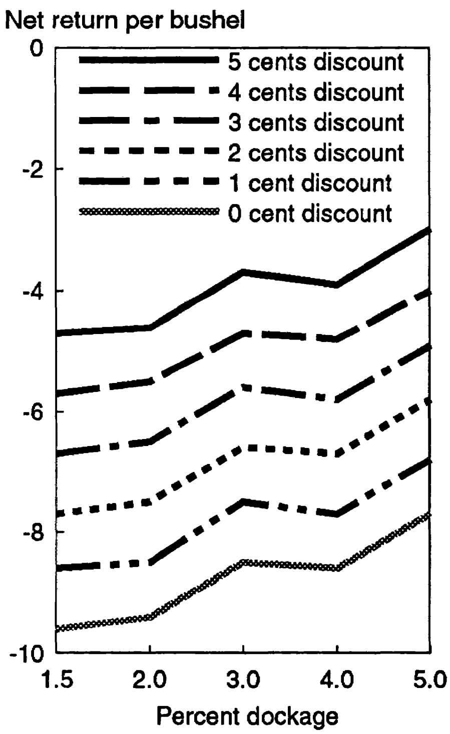


Based on 10,587 random samples of 1988 domestic wheat inspections.
Source: USDA, FGIS, 1988.

Farmers' net returns from wheat cleaning

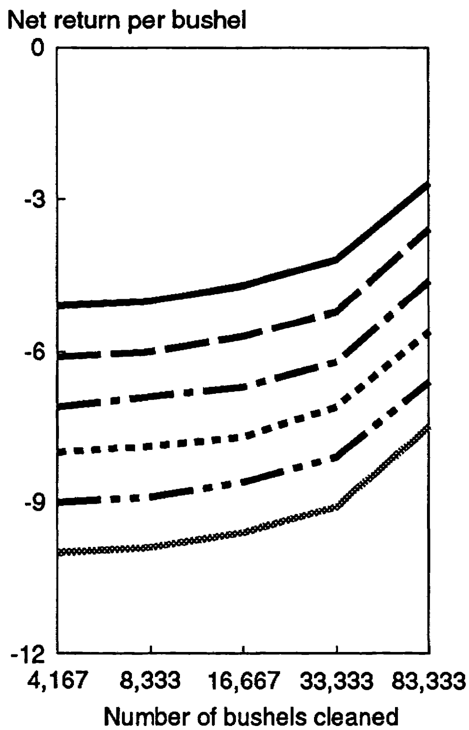
Appendix figure 7

By harvest dockage level



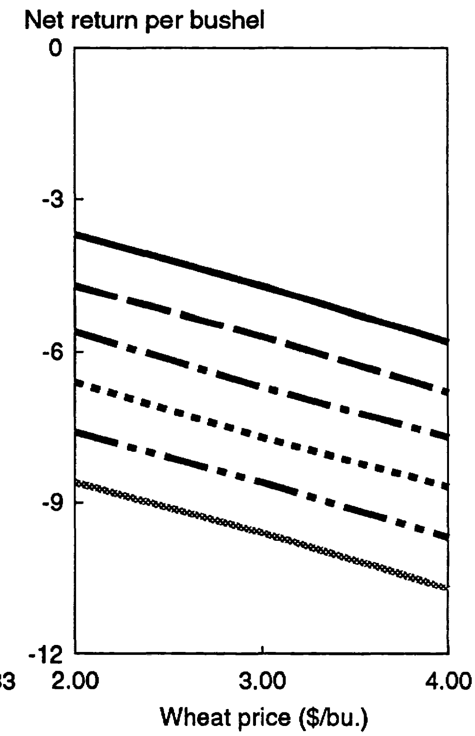
Appendix figure 8

By bushels of wheat cleaned



Appendix figure 9

By wheat market price



The estimated aggregate net cost of removing dockage on the farm with cleaners would range from $40 million to $238 million each year. This aggregate cost assumes that all wheat produced must have at least 1 percentage point of dockage removed prior to delivery.

Appendix E: Value of Cleanliness to Flour Millers

The value to flour millers of lower nongrain material in wheat depends on the price received for millfeeds. By taking the cost of cleaning as fixed, an analysis of value added to wheat can estimate the cost of mill screenings. The following illustration assumes (many more parameter combinations are possible):

- Wheat price of $150/metric ton (MT).
- Flour price of $330/MT.
- Transportation rate of $20/MT.
- Flour milling extraction of 25.0 percent.
- Millfeed yield of 23.5 percent.
- Milling loss of 1.5 percent.
- Tempering moisture changes from 12.0 to 16.0 percent.

Value added is the sum of the products produced from a raw material (wheat) times their selling prices less the cost of the raw material (including transportation).

With varying prices for millfeeds, to which mill screenings will be added, one can calculate the changes in value added for different screenings percentages. This difference in value added, in conjunction with the cleanliness that suppliers can provide, determines discount levels for the wheat market. Millers usually deduct the weight of dockage upon purchase. This practice significantly reduces the change in value added. For instance, a metric ton of wheat with 3-percent screenings (includes dockage, FM, and shrunken and broken kernels) when millfeeds are priced at $50/MT has a total value added of $98.83/MT. The total value added at 4-percent screenings is $97.90/MT. The difference, $0.93/MT (or 2.5 cents per bushel) would be the lost value to the miller for receiving 4-percent versus 3-percent screenings if there were no discount.

As the difference between wheat and millfeeds prices decreases, the discount becomes narrower, because the nonwheat material becomes a more valuable component to the miller. At a high millfeeds price, such as $100/MT, the value added drops from $112.27/MT at 3 percent to $111.72/MT at 4 percent, or about 1.5 cents per bushel. Taking the extreme case, where the millfeeds price equaled the wheat price, the difference in value added would be near zero. As illustrated in appendix figure 10, this flour mill would be indifferent to higher levels of screenings when the millfeeds price exceeded $150/MT. At higher millfeeds prices, the miller would actually earn more as a result of higher screenings. Wheat millfeeds prices averaged $84/MT during 1970-90.

Conversely, given these prices and this mill's operating characteristics, the miller would have a maximum discount of 3.6 cents per bushel per percentage point of screenings. This would occur if there were a zero price for millfeeds.