1988

Heterogeneous quality in the international trade of wheat

Bruno Larue

Iowa State University

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Heterogeneous quality in the international trade of wheat

Larue, Bruno, Ph.D.
Iowa State University, 1988
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by

Bruno Larue

A Dissertation Submitted to the
Graduate Faculty in Partial Fulfillment of the
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CHAPTER ONE: INTRODUCTION

Product quality issues for trade can be analyzed from many different perspectives. In a legislative context, traded goods must meet the quality standards specified in contracts between sellers and buyers. Contracts are instruments designed to compel both the seller and buyer to behave predictably and to facilitate the settlement of disputes that may arise. Because asymmetry of information can occur when either party has more knowledge than the other, the terms of the contracts may need to be regulated. For example, minimum quality standards are often imposed with the purpose of protecting consumers who have no access to information or who simply cannot process all the available information efficiently. These regulations are argued to be welfare improving, creating contracting in the public interest. In a more practical sense they reduce the number of disputes not only over quality, but also over such matters as delivery and pricing.

In economics, quality issues have been avoided, under the guise of 'simplicity' until recently. On a theoretical basis, it has been argued that goods of different quality must be treated as different goods; yet, goods of heterogeneous quality are often treated as homogeneous for legal purposes, such as in customs assessment and in
available data systems. But, it is undeniable that goods, like agricultural commodities, do differ in their intrinsic characteristics, such as visual appearance, weight, and nutrient content. An alternative argument, which states that goods with similar factor intensity and serving the same functions be treated as the same, has been only recently challenged. The Heckscher-Ohlin-Samuelson (H-O-S) model, outlined in Bhagwati and Srinivasan (1983) and used frequently by international trade theorists, assumes that products are homogeneous. It is, therefore, incapable of explaining the intra-industry trade prevalent between industrialized countries. Empirical analyses perhaps due to the aforementioned data features, often make no distinction between goods of different quality. This happens most frequently in demand analysis and commodity modeling. To simplify models empirical researchers abstract from the fact that different varieties may have distinct income effects (ex., Hard versus Soft wheat). The interpretation of results from these models using aggregate variables is frequently difficult.

In trade analysis, many economists have viewed a legislated minimum quality standard as an instrument whose main function is to protect domestic producers from foreign competition. Unfortunately, these standards can also deprive many consumers of the opportunity to purchase a
preferred quality. Legal issues regarding quality are different from economic issues. Legal issues restrict to the quality specified in a contract, whereas economic issues, such as expectations about quality and competition based on quality, go beyond contract specifications and concentrate on their influence on purchasing decisions and efficiency.

This dissertation uses wheat as an example of a commodity often differentiated on the basis of intrinsic characteristics. Seven types of wheat are sold in the United States. Each is differentiated by physical appearance, protein content, and milling and baking characteristics. They include: Hard Red Spring, Durum, Hard Red Winter, Soft Red Winter, White, Unclassed, and Mixed. The Hard Red wheats sell at a premium and are used for bread making. White and Soft Red wheats are used in bakery products, and Durum wheat is used to make pasta.

Motivated by depressed export sales and by increasing large number of complaints over quality, new regulations on the marketing of grain were introduced in 1986 (United States House of Representatives, 1986a). Wheat, which had drawn more than half of the complaints in 1985, seems to have been the main target. Related to the issue of market regulation are questions of the existence and identification of market failure(s) and the evaluation and
implementation of policies. Questions about the efficiency of the grading system and inspection services are also of interest. Can the quality of exported wheat be adequately assessed? Is quality deterioration occurring between the points of export and destination being minimized in the current marketing system?

The competitiveness of the U.S. grain export industry has been questioned in the quality debate. Are U.S. private grain exporters at a disadvantage by competing with government agencies? Assuming no other market failure, is the U.S. grain export market competitive enough for the exporters to have incentives compatible with public interest? Assuming that quality is not observable ex-ante (which implies that the price received by the firm depends on its reputation), is the number of exporters too high or is the structure of the industry causing export problems?

History of Grain Quality

Grain quality regulation goes back to thirteenth century Britain where a town ordinance barred London merchants from blending good corn with moldy corn (Hill, 1985). Ordinances from thirteenth century records also indicate that attempts were made to regulate the quality of corn in the cities of medieval France (Hill, 1985).
During the eighteenth century, the Parisian police were ordered to check grain and flour quality (Kaplan, 1984). They were concerned about grain, flour, and bread quality for two reasons. First, it was believed that, next to air, bread was the most common cause of epidemic maladies due to fraudulent bread making using contaminated water and bad grain. Secondly, Parisians demanded high quality bread, as depicted in their slogan, "Liberte, pain, et bon pain!" (Liberty, bread and good bread!). Millers were forbidden to mix any foreign matter, such as bran, barley or crushed chalk, into their flour. 'Honest' blending of flours of different quality was allowed only in 1752. A 1697 ordinance even regulated the use of fecal matter for fertilization of wheat land because of its supposed effect on wheat quality (Kaplan, 1984).

Historically, then, the grain industry was just as (if not more) regulated than it is today in the United States; and, the regulations used in the past were surprisingly sophisticated. Grain traders needed a license to operate, and police conducted spot inspections at every level of the industry. People who measured flour quality acted as arbiters of justice and of good faith between sellers and buyers, as well as keeping records of prices and supply. They were the 'watchdogs of commerce' (Kaplan, 1984). However, measures of grain quality differed in every
province, district, and almost in every French town. This made the marketing of grain and flour very inefficient by provoking disputes between sellers and buyers, and by reinforcing insular trade patterns.

The first grain quality grades in the United States were established in 1856 for wheat by the Chicago Board of Trade. A year later, grades were assigned to corn, oats, and barley. In 1858, official grain inspectors were appointed by the Boards of Trade in Chicago and Milwaukee (Hill, 1983). Later, in an effort to improve their marketing systems, individual states developed their own grading and inspection rules that were applied on a statewide basis. Much confusion followed, since the standards used in each state were quite diverse. Kitchen (1940) claimed that 338 names or grade titles existed in 1906: 133 for wheat, 63 for corn, 77 for oats, 53 for barley, 10 for rye, and one each for 'no-grade' and 'no established grade'. These grades did not serve their purpose very well. As of January 1st, 1899, the president of the Chicago Board of Trade had already received several complaints from individual exporters and English merchants about the unreliability of grain quality certification methods.

As early as 1890, Congress proposed that the federal government should control grain quality standards in the
U.S. The proposition was not popular among the Grain Dealers Association who were trying to establish their own voluntary standards. When their efforts failed, the Association eventually shifted their support to federal legislation. Twenty-seven years later, in fiscal year 1917, official grain inspection and grading under federal control was finally established.

The Grain Standards Act of 1916 prohibited both interstate and foreign grain shipments unless the grain had been inspected and graded according to appropriate U.S. standards. Only people who were granted a license by the Secretary of Agriculture were allowed to inspect grain and to issue U.S. certificates of quality (Ek, 1985; Hill, 1983; Kitchen, 1940). A system of appeals was established whereby dissatisfaction or disputes could be resolved by federal employees using the appropriate standards and procedures (Hill, 1985).

In 1940, soybeans were added to the list of commodities subject to official inspection (Ek, 1985; Hill, 1983), and the act was further modified in 1956, making both grain samplers and shippers liable for complicity when issuing false grade certificates (Ek, 1985; Hill, 1983). In an effort to speed up the movement of grain and to lower the cost of distribution, interstate inspections were made voluntary, rather than mandatory, in 1968 (Ek, 1985).
The most dramatic changes in the U.S. grain grading system took place in 1976 after numerous abuses of the 1916 law were uncovered. With the passage of the Grain Standard Act of 1976, the Federal Grain Inspection Service was born. Previously, grain inspection was the responsibility of the Agricultural Marketing Service whose role was restricted to inspection supervision, license granting, and appeals. This agency had had no jurisdiction over the weighing of grain shipments (Ek, 1985). Among other things, the 1976 law: (1) required federal weighing of grain arriving at, and inspection and weighing of grain leaving, U.S. export facilities; (2) extended Federal jurisdiction over weighing activities; and, (3) permitted the U.S.D.A. to delegate inspection duties to qualified state agencies (Ek, 1985).

In 1980, an amendment to the 1976 law was passed which exempted the following from official weighing requirements: (1) intra-company shipments of grain into an export elevator at an export port location; (2) grain transferred into an export elevator at an export port location by transportation methods other than barge; and (3) grain which is transferred out of an export elevator at an export port location for a destination within the United States; unless in each case either the shipper or receiver requests official weights (United States House of Representatives, 1980b).
In response to the large number of official complaints about U.S. grain quality from foreign purchasers, such as Egypt, Kenya, Japan, Korea, Portugal, Ecuador, Russia, and Israel (United States House of Representatives, 1986a), and to the decline in U.S. grain exports, Congress passed a bill in 1986 which was to improve the quality of U.S. grain provided to both domestic and foreign buyers. As stated in the Grain Quality Amendment Act of 1986, "... no dockage or foreign material, as defined by the Secretary, including dust, once removed from grain shall be recombined with any grain; and no dockage or foreign material of any origin may be added to any grain" (United States House of Representatives, 1986a).

Patterns and Trends in World Grain/Wheat Trade

The U.S. has been the dominant wheat exporter since the mid-fifties. This position in the world market had previously been held by Canada. Half of the total U.S. wheat production is Hard Red Winter wheat. Hard Red Spring wheat, which makes up roughly 90 percent of the Canadian production, accounts for only 20 percent of production in U.S. These production figures reflect the harshness of Canadian winters which prevent the higher yielding Winter wheat from being successfully grown in Canada. The limited rainfall in western Canada contributes to a widening of the
gap between the yields of U.S. and Canadian wheat. On the other hand, the dryer climate increases significantly the protein content of Canadian wheat. It is for these reasons that strategically, the U.S. and Canada have historically focused on quantity and quality, respectively, in production and marketing policies. The export market for medium quality wheat has more participants than the market for high quality wheat. This is consistent with the technological advances which have taken place in the milling and baking industries, reducing the premium for hard wheats. The increased degree of substitution between medium and high quality wheat has forced Canada to reevaluate a strategy, which has concentrated on production and marketing of harder, higher quality wheat.

It has been widely publicized that U.S. wheat exports decreased steadily during the interval from 1981 to 1985 (Figure 1-1). While the United States is still the leading exporting country for wheat, it has recently lost a significant share of the market. In contrast, countries like France and Australia have seen their market shares raise substantially between 1982 and 1985. Argentina's wheat exports boomed between 1982 and 1984, only to return to their previous 1981 level in 1985 and 1986. In contrast, Canada's exports have been fairly stable overall. Like the U.S., Canada lost part of its market share to
FIGURE 1-1. Wheat exports by country
other major exporters during the period 1983 to 1985. Coinciding with the passage of the 1986 U.S. Grain Improvement Act and the heavy export subsidies of the 1985 Farm Bill, the trend turned in 1986 and the U.S. regained a small share of the market it had lost, while Canada's exports were very close to their 1983 level.

U.S. wheat production and stocks, the highest among the main wheat exporters, increased between 1981 to 1986 (Figures 1-2 and 1-3). Given the overall increase in stocks and the decrease in production, we can conclude that the depressed exports were not the consequence of higher domestic demand. France's production increased slowly but steadily until 1984. This contributed significantly to the metamorphosis of the European Economic Community (E.E.C.), which was the largest wheat importer, into a major exporter. As a rule, the wheat production of U.S. competitors has experienced fluctuations of a smaller magnitude than U.S. production with perhaps the exception of Australia between 1977 and 1986. A striking difference between the U.S. and the other wheat exporters is the size of U.S. stocks (Figure 1-3). Having distinctive different agricultural policies, Argentina, Australia and France do not hold Government controlled stocks.

The exported share of the wheat produced by the five largest exporting countries are displayed in Figure 1-4.
FIGURE 1-2. Wheat production by country

ARG.  AUS.  CAN.  FRA.  U.S.
FIGURE 1-3. Wheat inventories by country
FIGURE 1-4. Ratio of exports to total wheat production
The shares of exports in the total disappearance of wheat in the U.S. and Argentina were below 50 percent in 1986. Australia, Canada and France had relatively smaller domestic demand with export shares of 0.90, 0.70 and 0.55, respectively. Figure 1-5 shows that the importance of feed in the domestic demand of wheat is lowest in Argentina (five percent) and in the U.S. (30 percent). This figure also reflects differences in feeding practices between Canada, where wheat and barley are popular feed grains, and the U.S., where corn is more commonly used as feed.

Several reasons can be advanced for explaining the performance of American exporters in recent years. For example, the U.S. dollar may have been over valued, thus rendering U.S. exports more expensive for foreign importers. This argument has short term merit, but, if one believes in the strong form of purchasing power parity and in relative prices determining the exchange rate, it is limited as a longer run explanation. Political scientists, on the other hand, might hypothesize that there has been a growing unpopularity for U.S. foreign policy, contributing to the fall of U.S. grain exports. The explicit and implicit export subsidies used by U.S. competitors have also contributed to the decline, and relegating these arguments to a minor role would be misleading.
FIGURE 1-5. Ratio of feed use to total use of domestic wheat by country
Recognizing the potential role of exchange rates, export subsidies, and foreign policy is one thing, but these factors may not be the only significant ones. Many people, including Iowa Congressman Neil Smith, believe that the uncertain (and/or lower) quality of the grain exported has been a major factor contributing to the decline in U.S. grain exports. With high hopes of remediying problems with grain quality, the U.S. Congress passed the Grain Quality Improvement Act of 1986 to amend the Grain Standards Act of 1916. This bill has been controversial, and has not effectively reduced the number of foreign complaints, nor has it increased exports.

**Grain Quality Issues**

Wheat is not a homogeneous product. The grain differs in kernel size, protein content, moisture level, number of broken kernels, amount of foreign material, etc. Full information for buyers and sellers or simply standardization of grain quality grading systems contributes to efficient marketing. In the absence of standardization and if history repeats itself, the market for information about grain quality will be inefficient and production, selling, and purchasing decisions will not be Pareto optimal. Quality uncertainty does not necessarily imply inefficiency. Pareto optimality can be achieved if
perfect contingent markets exist. Identical attitude toward risk by all the market participants is obviously a sufficient condition to prevent the creation of such markets since for every market there has to be a supply and a demand. These contingent markets have to be competitive for the economy to be Pareto efficient. Alternatively, a standardized grading system improves marketing efficiency by enabling the warehousemen to mix grain of the same grade rather than segregating loads that individual producers bring to the elevator.

Marketing flow

As illustrated in Figure 1-6, a typical flow from seller to buyer in the U.S. consists of grain transported by truck from the producer to the initial purchaser, usually a local county elevator. Before the grain is turned over to the elevator, the warehouseman weighs the grain and checks it for moisture, foreign material and broken kernels. After storage, the grain may again be weighed and sampled by the next buyer before it is transported by truck or rail to a large terminal elevator (additional 'subterminal' elevators may also be part of the distribution chain).

At this point, the grain may move either into domestic channels, in which case the terminal elevator sells
FIGURE 1-6. Marketing flow for U.S. wheat
directly to a U.S. processor, or the grain may be contracted to an overseas buyer. In the latter case, the terminal elevator will ship the grain by train, truck, or barge to a U.S. port elevator. While official grain weighing and inspection at inland locations, by either the Federal Grain Inspection Service (F.G.I.S.) or an agency contracted by F.G.I.S., is not mandatory, it may be performed upon request. In contrast, the grain is weighed and inspected by F.G.I.S. when it is loaded from a port elevator onto an ocean vessel (Ek, 1985; United States House of Representatives, 1980b).

In Canada, the Canadian Wheat Board (C.W.B.), is responsible for the marketing of wheat with the exception of feed wheat which is under the jurisdiction of the Canadian Livestock Feed Board. Like their American counterpart, the Canadian wheat growers have the option of selling feed wheat directly to livestock producers, feed mills or to private elevators, such as Pioneer or Cargill. Their other option is to market wheat as a foodstuff through the C.W.B. which allocates delivery quotas among wheat growers. A fundamental concept employed by the C.W.B. in paying producers is price pooling. The farmers receive an initial payment for the wheat they deliver at the country elevators as contracted with the C.W.B. At the end of the year, the profits made by the C.W.B. are shared
among pool participants, according to the size of their quotas. Export sales are either negotiated directly by the C.W.B. or by private trading companies acting as agents for the C.W.B. The Canadian Grain Commission is responsible for grading wheat. A distinction between U.S. wheat exporters and the sole Canadian exporter is that, according to the Wheat Board Act of 1967 (Wilson, 1979), the goal of the C.W.B. is to maximize the wheat growers (long-run) profits. In the U.S., exporter and farmer interests can be in conflict, given the potential use of monopsony power by exporters.

**Grading of wheat**

Wheat is first judged as a class, then as a grade. As noted before, classes are differentiated by such features as physical appearance, hardness, and growing habit (North American Export Grain Association, 1986). In contrast, wheat grades are influenced by seven specific factors: test weight, heat damage, total damaged kernels, foreign material, shrunken and broken kernels, total defects, and wheat of other classes (Ek, 1985). A wheat quality designation must include not only the class and grade
number, it must also indicate the amount of dockage\(^1\) in the wheat, and whether it contains infestation (Ek, 1985).

If a given load of wheat scores high on six of the grading factors and fails to meet the minimum requirement for a seventh, it will be given a grade corresponding to the grade scored on the lowest factor. Consequently, farmers or warehousemen who anticipate that their grain will score low on one factor have no incentive to maximize scores on the remaining factors. It can be deduced that this grading system may not operate in the best interests of all parties involved. Substantial variability in quality may exist within a designated grade.

Test weight is a measure of grain density. It is determined by weighing the quantity of grain required to fill a one quart bucket. This weight is then converted to bushel equivalent (Hill, 1983). When buyers purchase a bushel of wheat, they receive sixty pounds of wheat, regardless of its test weight. Test weight is computed to determine the space that will be needed to store or transport the wheat. A bushel of wheat with a low test

\[^1\text{The U.S.D.A. defines dockage as, "All matter other than wheat which can be readily removed from a test portion of the original sample by use of an approved device.... Also, underdeveloped, shriveled, and small pieces of wheat kernels removed in properly separating the material other than wheat which cannot be removed by properly rescreening or re-cleaning."}\]
weight will need more space than a bushel with a higher test weight. According to Hill (1983, p. 136), test weight has little economic importance, especially for corn, and should not be included in grain grading systems. He notes that, "Research at several universities has shown almost no relationship between test weight and feeding value, nor has research shown any relationship between test weight and processing value, yet we continue to downgrade and discount light test weight corn." Charles Hurburgh, an authority in grain quality issues at Iowa State University, disagrees. He hypothesizes that many grain buyers associate high test weight with low occurrence of grain quality problems and desire to know test weights. He claims that recent research validates the use of test weight as a quality criteria.

In the past, moisture content has also been a grading factor for corn and soybeans.² Though moisture content is no longer a factor in grading, a given moisture content may be specified separately on any contract. When such an arrangement is requested by a buyer, grains with low and high moisture contents are often mixed together in order to achieve the given requirement. Unfortunately, this practice also makes the grain more susceptible to spoilage.

²Moisture was a factor in grading corn, sorghum and soybeans until September, 1985 (Ek, 1985).
or infestation when the difference in moisture levels is higher than four percent (North American Export Grain Association, 1986).

When moisture was a grading factor, it had two opposite effects on the price farmers received for their grain. It had the direct effect of discounting prices when grain failed to meet maximum moisture requirements, but a beneficial indirect effect resulted from the positive correlation between moisture and weight. Most farmers were storing grain at moisture levels below the maximum allowed. Some would then add moisture to attain the maximum allowed because the loss of weight associated with dryer corn was not compensated for by higher prices (Hill, 1985, p. 412). Moisture standards for pricing were inefficient since they were not compatible with optimum moisture levels for storage and processing.

Hill (1985) has suggested that grain should be sold solely on dry matter per bushel without consideration for water content. His rationale was that buyers are seeking grain with high quality feeding value, and water does not contribute to feeding value. However, wheat moisture level is important, not only because it can change weight, but because it can affect the reporting of protein content. In the past, protein was reported as a percent of the total weight of a sample. Proteins at different moisture levels
can be converted for comparison, but unless otherwise requested, F.G.I.S. did not adjust the protein content for a standard moisture level. Now, as proposed by the North American Export Grain Association (1986, p. 6), a 12 percent moisture basis is used as a standard.

Many factors contribute to the broken kernels and dust found in grain shipments. The problem starts at the farm level. For corn, the Dent variety, which is predominantly grown in United States, is very susceptible to breakage. Breakage is most likely to occur during the drying process, especially during a high speed drying process. Breakage will also occur each time the grain is loaded or unloaded, and, as a result, dust will accumulate. As a rule, it is estimated that each time U.S. grain is handled, there is one percent breakage (Ek, 1985). When grain is loaded, dust filters to the top of the container due to its light weight. This dust gives a negative impression to a buyer looking into the hold of a ship, and will contribute to quality heterogeneity within a load.

Hill (1983) suggested that brittleness should be a factor in grading corn so that farmers would have an incentive to produce corn less likely to break, by drying it at lower temperatures and by growing varieties more resistant to breakage. Hill (United States House of Representatives, 1986a) recommends that foreign material
and broken grain be reported separately, as in Argentina, and that grade limits be set near zero with discounts for grain delivered below standard. While broken kernels are not desirable, producers prefer broken kernels over weed seeds or dirt; therefore, the grading system should be adjusted accordingly.

The high number of broken kernels is a serious problem for countries importing wheat from the U.S. Malaysia, Italy, Sweden, Venezuela and Jordan have all officially voiced their dissatisfaction with the number of broken kernels in their wheat purchases from the U.S. Until 1986, U.S. exporters would over clean their grain by removing dust and foreign material. Then, in order to efficiently satisfy the requests of different importers, a given amount of foreign material, dust or broken kernels, would later be reintroduced to meet contract specifications.

The Grain Quality Improvement Act of 1986 banned the reintroduction of dockage or foreign material of any origin into grain (United States House of Representatives, 1986a). However, Section 3, (c)(2) restrains enforcement of this ban by stating that exporters are not prohibited from,

"(C) the blending of grain with similar grain of a different quality to adjust the quality of the resulting mixture; ...;

"(E) ...the recombination of dockage or foreign material, except dust, removed at an export loading facility from grain destined for shipment as a cargo under one export official certificate of inspection when the re-
combination occurs during the loading of the cargo, when the purpose is to ensure uniformity of dockage or foreign material throughout that specific cargo, and when the separation and recombination are conducted in accordance with regulations issued by the Administrator; ...;

"(G) any other addition of foreign material that may be determined by the Secretary to be in the interest of grain producers and to be neutral or constructive in achieving the goal of ensuring the quality of grain marketed in or exported from the United States" (United States House of Representatives, 1986a, p. 2).

Since the cost of removing dockage is supposedly increasing at an increasing rate, most contracts allow for a specific tolerance level. To the displeasure of many foreign buyers, dockage was rounded to the nearest 0.49 percent in the U.S. grading system until May of 1987 (i.e., grains with zero percent dockage received the same grade as grains with 0.49 percent, while grains with 0.51 percent will receive a lower grade). Foreign buyers paid dearly for that extra non-wheat material, especially when one takes into account costs for transportation of the dockage and import duties that are often set on a straight tonnage basis. The dockage is now rounded at the nearest 0.10 percent. Also of concern was the possibility that the range of values between grades for some factors would be too small. For example, the probability of obtaining a correct grade for No. 2 corn on the basis of heat damage is less than one half (Hill, 1983, p. 136).
Foreign markets and quality

In reference to foreign complaints and contract specifications, Dr. K. A. Gilles, Assistant Secretary for Marketing and Inspection Services at the U.S.D.A., reported that among 30 formal complaints filed by foreign grain buyers during the first ten months of 1986, none were valid (United States House of Representatives, 1986a). The grain, as documented, appeared to have met contract specifications, but this apparently did not mean much to these dissatisfied foreign buyers. Under current inspection regulations, grain is sampled as a vessel is loaded and the responsibility of the U.S. exporter for the quality of its grain ends. Any grain quality complaints that are based on the quality of grain received at destination are resolved with reference to the accuracy of the original certificate issued at the time of loading, not on changes in quality thereafter (Hill, 1983). As a result, foreign buyers are detrimentally affected if the imported grain is susceptible to breakage and infestation during the handling and shipping that occurs after it has been loaded.

Occasionally foreign buyers receive infested grain. As noted by Ek,

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3 During the last three years, 178 complaints were lodged and only one was judged valid after investigation.
"Insect eggs, because of their minute size, are extremely difficult to detect. Even though a grain shipment may be certified as 'insect free' before a vessel leaves its home port, eggs may hatch after the ship sails and the buyer may receive an infested load of grain. Infestation was cited nine of the 65 foreign quality complaints logged in the first eleven months of FY 1985" (Ek, 1985, p. 33).

If an importer can prove that the grain was infested at the point of export (i.e., if the samples taken from the vessel are found to be infested), the importer is entitled to some compensation. Yet, despite this compensation (adequate or not), the reputation of the exporting firm might suffer.

As shown in Figure 1-7, the number of foreign complaints has recently been high: 13 in 1983, 22 in 1984, 73 in 1985, 45 in 1986, and 59 in 1987. The high number of complaints in 1987 is disturbing for two reasons. First, it seems that the 1986 legislation on grain quality has not been effective in fulfilling the stated objective. Secondly, the importers may eventually stop complaining and will purchase their grain from other exporting countries. Alternatively, they may try to reach a higher level of self-sufficiency. As a result, the U.S. may become a supplier of last resort for many importing countries.

Most U.S. competitors (except Canada who, like the U.S., uses the certificate final system) adopt a system in which grain quality is determined at the point of destination rather than at the point of loading (Hill,
FIGURE 1-7. Number of foreign complaints for all exported grains, 1977-87
1983). Under the "Fair Average Quality" system (F.A.Q.), the price is determined by comparing the quality of a particular shipment with the average quality of all shipments received during a month for such grain. A standard for a given exporting country is made up of the average quality of all the grain delivered (at all destinations) each week by all the exporters of that given country. The samples, which are collected according to the contract specifications, are analyzed by the Grain and Feed Trade Association in London which set the quality standards.

Foreign buyers face uncertainty when purchasing U.S. or other grains. The certificate issued by F.G.I.S. tells the importer that the grain was of acceptable quality at the point of export, but the quality of the grain, once it reaches its destination, may have deteriorated. The degree of deterioration is random, fluctuating from shipment to shipment and probably from one class of wheat to another. The F.A.Q. system generates uncertainty, too, since the standard of comparison used in pricing varies from year to year. In addition, there is uncertainty in the process of assigning quality grades. As noted previously, grain that scores low on only one factor receives the same grade as grain scoring low on all factors. This potentially creates heterogeneity within a given grade. Canadians, in
contrast, are known to export wheat with more consistent quality that tends to score higher on most grading factors than the minimum standards specified in contracts or in the Canadian grading system. This may partially explain why roughly half of the contracts negotiated by the Canadian Wheat Board are on a long term basis (Carter, 1983).

As pointed out by Hill (1985), the most dramatic quality problem in the U.S. international markets may be that many of the quality factors important to foreign buyers are not reflected in the U.S. grading system. Consequently, there are no incentives at any point in the marketing channel to improve those quality characteristics that are important to foreign buyers. These factors can vary in quality irrespective of the grade assigned, thus further increasing quality uncertainty and rendering the grading system inefficient.

Objectives of the Analysis

The issues selected for investigation in this study were chosen primarily because they have been ignored or misunderstood in the past. Because of the private nature of data on wheat quality, some relevant empirical applications of the conceptual model were not investigated. Considerable attention has been devoted to the identification of the problems. We analyzed, from
different perspectives, the behavior of an importing
country facing changes and uncertainty in the quality of
its imported wheat. Once identified, the objective was to
find the cause of the problem. Of interest are the factors
responsible for the seemingly irrational behavior of U.S.
wheat exporters.\(^4\)

Quality issues are complex because the effects of
wheat quality on imports cannot be isolated. This stems
from the existence of other significant factors affecting
jointly and separately the purchase decisions of importing
countries. Even if there were data available, the choice
of the key characteristics used to compare wheats of
different origin would be an issue by itself, since
different classes of wheat serving different purposes may
define individual sets of characteristics.

The issue of public versus private exporting firms is
partially addressed in a reputation analysis. Questions on
the need to create a government agency or to allocate
licenses between exporting firms are raised. The barter
trade issue between two countries, supposedly favoring
government agencies, has been omitted. The effect of price
uncertainty on the exporter's behavior regarding quality is

\(^4\)Under some conditions, a profit-maximizing firm can
rationalize deterioration in its reputation. This is
elaborated in Chapter Five.
investigated. The impact of quality changes and uncertainty on foreign demand for U.S. wheat is one of the main issues analyzed in this study. Of equal interest is the rationale used by U.S. exporting firms to justify supplying wheat of somewhat lower or uncertain quality to importing countries. These issues were selected as opposed to traditional pricing because the latter cannot be adequately resolved given the quality of data presently available.

Theoretical Developments

The endogenization of quality is a fairly recent phenomena in models of trade and consumption (Falvey, 1979). The study of trade barriers in a quality context is even newer (Das and Donnenfeld, 1987; Krishna, 1987). And, the study of the impact of quality uncertainty on the volume of import and domestic production is novel. As noted before, the role of quality in the making of the reputation of an exporting firm is discussed. The reputation of the firm/country is introduced because of information problems related to quality.

Quality can be modeled in many different ways. In general, the approach chosen varies according to the nature of the good and the production function or preference structure of the users of the good. In the pioneering work
of Lancaster (1971), quality was modeled as a vector of key characteristics. Wheat is a commodity whose quality is represented by a scalar or grade. A quality parameter \( q \) for imported wheat is introduced to make a bridge between wheat of different qualities. The product of the volume of imported wheat \( Q \) and the quality parameter \( q \) can be interpreted as imported wheat in terms of domestic quality. The quality parameter is a relative grade which uses the quality of the domestic wheat as the numeraire. It can also be viewed as the relative number of 'indexed' characteristics of imported wheat.

Borrowing from the 'reservation wage concept' used by labor economists, an alternative approach would be to have a reservation quality level \( q_t \). Wheat at or above the \( q_t \) threshold can be judged as usable. This implies that the production function of wheat importers must have the following properties:

\[
\begin{align*}
    f(q, Q) &> 0 \text{ for all } q \geq q_t \\
    f(q; Q) &= K \text{ for all } q \geq q_t \\
    f(q, Q) &\approx 0 \text{ for all } q < q_t.
\end{align*}
\]

Again, the quality variable is defined as \( q \); and, \( Q \) stands for volume of wheat used in the production process. The quality of the imported wheat is assumed to be normally distributed. The probability, \( \theta \), that imported wheat will be usable depends on the reservation quality level, \( q_t \), and can be defined as
This approach has the advantage of reflecting the notion of 'minimum quality level'. Minimum quality level is the basis for most grading systems, and is intended to reflect the preference structure of the buyers. Another advantage is the introduction of a second quality parameter, variance. The 'frills' approach, used mostly by economists in the field of industrial organization, does not apply in this case because 'quality units' cannot really be added to a 'basic' kernel of wheat. The 'frills' approach would be appropriate for processed grain, such as sugar-coated cereal flakes.

Finally, the first reputation model used in the analysis is similar to Shapiro's model, and is based on lagged quality supplied by the exporting firm. A second model hypothesizes that the reputation of an exporting firm is country-specific. This implies that the price received by a U.S. firm depends on the quality it supplies as well as the quality supplied other U.S. firms. Reputation can be viewed as a function of the different levels of wheat quality produced in the exporting country. This latter case is simply an attempt to analyze the externality impact associated with the introduction of lower quality/higher
yielding varieties which cannot be visually distinguished from the higher quality variety.

Procedure and Application

The general objective of the dissertation is to better understand the implications of the market failures in the wheat export market. This objective is achieved using simple theoretical models. The introduction of a quality dimension limits substantially the scope of these models. For clarity, the market power issue is, at times omitted. When this is so, introducing market power does not change the basic results but only raise the degree of complexity. The assumption of identical taste within an importing country is not relaxed anywhere. This subject is well documented and is not central to the theme of the research (Bridgeman, 1985; Bond, 1984).

The main advantage of theoretical results are their flexibility. In a theoretical framework, there is no need for assumptions about functional form to fit the data. Effects of other factors can be abstracted, greatly facilitating the interpretation of the results. However, the fact that a theoretical framework does not enable us to rank model specifications is a shortcoming that should not be underestimated.
The absence of any econometrics is by design. There is little justification for performing an econometric analysis on very short data series of unreliable quality. No data on the 'relevant' characteristics of wheat of different origins have been assembled by an unbiased source. Moreover, the price series published by the International Wheat Council and others are asking prices, not transaction prices. These asking prices are the suppliers' first quotes in the bargaining process.

To compensate for the absence of direct empirical testing of the hypotheses from the theoretical models, we use tables and graphs of relevant aggregates to add to the credibility to our results and to facilitate in a loose sense their quantitative impacts.

Organization of the Dissertation

The following chapter, Chapter Two, is a review of the relevant literature on quality and uncertainty. The first section of that chapter focuses on risk and uncertainty in economics. Papers on trade policies and the non-equivalence of tariffs and quotas are reviewed briefly in the second section. Papers on quality of goods and trade policies are also included. The last topic investigated is that of the reputation of a firm.
In Chapter Three, a simple quality parameter 'q' is introduced in a standard utility maximization problem. In this problem, a country is importing wheat whose relative quality is summarized by q alone. It is assumed that the price of the imported wheat is not responsive to small changes in its quality and that consumers and producers can react instantaneously to such changes. The adjustments that necessarily take place in the importing country when quality fluctuates are analyzed by standard comparative statics methods. From the first order conditions, we show that an efficient equilibrium is reached when the domestic rate of transformation is equal to the price of the imported good divided by the quality parameter. It is shown that as the quality of the imported good decreases, the quantity imported decreases or increases depending on the size of the price elasticity for the imported wheat. The indirect utility function for this 'quality' problem is also used. It is reported that an increase in the quality of the imported good is welfare improving (when, as usual, distribution issues are ignored).

Chapter Four deals with the model from Chapter Three in the case of uncertainty. Using an expected utility framework, it can be shown that imports of uncertain quality will induce the importer to increase domestic production. The impact of a marginal increase in
uncertainty on domestic production and imports (à la Sandmo-Ishii's mean preserving spread) appears ambiguous.

The first part of Chapter Five builds on Shapiro's (1983) work. Political events, such as embargoes, may affect the behavior of a firm by changing the subjective probability of a shorter series of profits. In the end, the firm may be more susceptible to 'milk' its reputation in return for quick profits. It may market goods of low quality as goods of high quality to importers who take 'n' periods to discover the true quality of their purchase. The case of a country-specific reputation, where the reputation of a firm depends on the quality of the goods exported by all the firms in that country, is investigated. In this case, all firms behave as free riders, and, as a result, both quality and reputation decrease. Different policies are compared for a model in which the firms have some market power.

The last section of Chapter Five develops a model in which the importers have imperfect inspection systems and have a probability 'α' that they will be unable to discriminate low from high quality. It is assumed that the importers take only one period to discover the true quality when they cannot discriminate the goods in the current period. In one case, the importers are assumed to know the
exact levels of production of low and high quality wheats and they are able to use that information in conjunction with $\alpha$ to change their demand for the high quality wheat. Low and high quality wheat could be perfectly discriminated when $\alpha = 0$, but when $\alpha > 0$ (from the introduction of look-alike new varieties) the price of the low quality wheat becomes relevant in the pricing of high quality wheat, even though both qualities may serve completely different purposes. It is demonstrated that the introduction of new varieties may involve a decline in the export sales of both wheats.

In Chapter Six, the consumers of imported wheat have a reservation quality level. Wheat of quality below that threshold is not an argument in the utility and/or production functions of the buyers. In the first model, the importers of U.S. grain maximize their consumer surplus via a willingness to pay function (Bridgeman, 1985), which depends on the reservation quality level, the mean and variance of the quality. The inefficient price mechanism is characterized as a function of the mean quality, which implicitly means that blending is not discounted. The importers response to an increase in variance (the result of blending and/or the reintroduction of foreign material) is investigated. The response of the importers obviously
depends on the location of the threshold in the quality distribution.

To analyze the effect of different trade barriers on the exporter's choice variables (quantity, mean, and variance quality), a model in which the price received by the exporter depends on the probability that the quality of the exported wheat will be above the importer's reservation level was designed. In accordance with recent literature, trade barriers will induce the exporter to increase the (mean) quality. The new result is that variance will also be augmented. The last question addressed is how price uncertainty affects the quantity and quality choices made by exporters.
CHAPTER TWO: UNCERTAINTY AND QUALITY VARIABILITY

This study is about risk, uncertainty, trade and product quality. More specifically, it concerns trade policy and quality uncertainty. The review of the literature on this subject is divided into two sections. First, results from studies on risk, uncertainty and trade policy are reviewed. This is followed by a discussion of the quality issue as it has been treated in economics. Topics also included are intra-industry trade and product variety, reputations of firms and product quality, and how trade restrictions are used by importing countries to influence the quality of the imported goods.

Risk, Uncertainty, and Trade Policy

Literature on risk and uncertainty is germane to the issue of grain quality because importers often face uncertainty in the quality of wheat supplied by exporting nations. The following review explores theoretical and methodological developments in the area of risk and uncertainty. The methodology and results presented in this section serve as a foundation or framework for analyzing the effects of uncertainty in the international trade of wheat.
Price stabilization

Usually, risk and uncertainty are directly associated with price uncertainty and stabilization. Numerous results exist on the subject. The controversy surrounding price stabilization efforts emerged with the publication of a paper by Waugh in 1944. Waugh (1944) used Marshallian consumer surplus as a measure of welfare and compared a situation where price was uncertain (due to shifting of an upward sloping supply curve) with a situation where price was stabilized at its arithmetic mean. He concluded that consumers benefit from price instability.

While Samuelson (1972) interpreted Waugh's findings to mean that managed or artificial price instability was beneficial, this seems not to have been Waugh's intention. Waugh's investigation was motivated by agricultural markets in which prices were initially unstable. He then analyzed the benefits of stabilizing the price at its arithmetic mean, not vice versa. As he wrote, "...consumers might make real gains by taking advantage of the price fluctuations, which were foreseen instead of prevented" (1944, p. 613). Thus, Samuelson's criticisms were not directly relevant to Waugh's result. Samuelson was actually discussing a related, but quite different problem.

Using Waugh's framework, Oi (1961) analyzed the effect of price stabilization on producers. He also found that
instability (of the demand curve in this case) was beneficial when producers are allowed to react instantaneously to the associated price variation. Massell (1969) combined both Waugh's and Oi's analyses and concluded that stabilization is socially desirable given the assumptions employed by Waugh and Oi.

Van Kooten and Schmitz (1985) replicated the stability analysis using the assumption that producers had to make their production decisions before the realization of the market price by picking a price ex-ante. In essence, they used a partial equilibrium model to assess the impact of price stabilization under price uncertainty, not under price instability. The supply curve was, consequently, infinitely inelastic as opposed to the upward sloping curve used in previous analyses. This somewhat modified previous results.

Risk and decision analysis of the firm

Some of the most significant results on risk and uncertainty were obtained by Baron (1970) and Sandmo (1971). Using different methods, their studies prove that a risk averse producer will produce less than a risk neutral or risk lover when price is uncertain which clearly contradicts the result of deterministic theory. Their work provided a much needed extension of the neoclassical theory
of the firm which at the times could not satisfactorily explain observed behavior. The major departure from the work of Baron's (1970) contemporaries lies in the relaxation of the assumption of instantaneous output adjustment to uncertainty (instability). Baron (1970) showed that it is risk aversion, not uncertainty, that causes expected profits to be positive in a competitive equilibrium. Risk aversion explains why output is not at the most efficient level. It is also shown that the short run supply curve need not be positive under uncertainty. Sandmo's (1971) contribution can be seen as a very successful attempt to analyze the behavior of the competitive firm under uncertainty without assuming that the firm maximizes expected profits. Included in his paper is a stimulating discussion on risk aversion and market structure. However, the issues of product diversification, market power, and investment in a dynamic context still had to be addressed.

Arrow (1971), Pratt (1964), and Rothschild and Stiglitz (1970, 1971) also made substantial contributions to the field by defining and analyzing some of the implications of risk aversion. Pratt (1964) and Arrow (undated lecture notes) can be credited for being the first to define the concept of risk aversion and its reciprocal, the insurance premium. The implications of specific
functional forms for utility functions are analyzed by Pratt (1964). These specific forms have been used extensively since that time. Pratt's (1964) methodology has been particularly influential. His elegant derivations have inspired the work of many economists including Baron (1970). Rothschild and Stiglitz (1970) prove that the concept of increasing risk is, in general, not equivalent to that implied by equating the risk of a random variable with the variance of that random variable. Their use of a mean-preserving spread of the distribution of a random variable has been borrowed by many.

Factor demand

The implication of output price uncertainty on factor demand became a very popular topic in the mid-1970s (Batra and Ullah, 1974; Holthausen, 1976; Hartman, 1976). Batra and Ullah (1974) claimed that a risk averse firm under output price uncertainty will produce less than when under certainty, and therefore it will use less of all inputs. Excess capacity would imply that the marginal value product of the factor will exceed its price. This holds only if the inputs are normal. Even if a risk averse firm produces less under output price uncertainty than in a situation of price certainty, it will still minimize its costs given the output level it has chosen and produce somewhere on its
expansion path. The levels of inputs used when output is reduced depends in the curvature of the expansion path. If the latter has at least one 'bubble', then Batra and Ullah's results will be wrong.

Holthausen (1976) investigated the situation where a firm uses a predetermined level of capital and a variable amount of labor to produce its output. The firm faces an uncertain demand for its output, and, because of the fixity of capital, must choose the desired level of capital before the uncertainty disappears. The perfectly competitive firm selects the same input combination as under certainty for the same output level (i.e., the firm selects output and capital levels ex-ante and implicitly chooses the amount of labor by examining the expansion path). A different input mix is used by a price-setting imperfect competitor who is allowed to determine its output ex-post (i.e., labor is used to compensate for changes in output).

In yet another model, Hartman (1976) assumed that a firm uses two inputs, and that one of those inputs must be purchased ex-ante. It is shown that uncertainty alters the relative demand for factor inputs. The direction of the change is ambiguous and depends on the assumptions made about the nature of the production function.

In the late 1970s, a number of results were developed examining the topic of factor-price uncertainty (Stewart,
1978; Perrakis, 1980). According to Stewart (1978), "Compared with a risk-neutral firm, a risk-averse firm uses less of the risky input and more of the fixed-price input...." Perrakis's (1980) paper was written as a critique of Stewart's earlier work. Among other things, Perrakis argued that risk neutrality and uncertain input prices yield a different input mix than under certainty, and that Stewart's main result holds only when there is a single variable input.

International Trade

In Chapters Five and Six, different trade restrictions are compared. In Chapter Five, regulations are imposed on the wheat export industry with the objective of forcing the firms to supply a quantity and quality mix more in line with the country's relative position in the world market. In a situation where the wheat importers have a reservation quality level, the effects of trade restrictions are compared in Chapter Six. For this reason, major articles on the non-equivalence of tariffs and quotas are reviewed in this section.

Trade restrictions

International trade theorists had studied various aspects of the equivalence (or non-equivalence) of tariffs and quotas. In 1965, Bhagwati found evidence of non-
equivalence when the import sector is not competitive. Rodriguez (1974) also found that tariffs are superior to quotas when foreign retaliation is considered. Since some trade remains when the countries involved in a trade war use tariffs, they still derive a potential benefit from trade. Building on Rodriguez' work, Melvin (1986) explained that the possible equilibria reached when two trading countries simultaneously use trade barriers differ depending on the type of trade barriers used. Some of the equilibria attained with tariffs are not feasible if the two countries alternatively imposed quotas.

Risk and uncertainty was only recently introduced into economic analyses of international trade. Weitzman (1974) compared price and quantity controls used to regulate production of a good with uncertain costs and benefits. Then in 1976, Fishelson and Flatters (1975) and Pelcovits (1976) compared the use of tariffs versus quotas in international trade in the presence of uncertainty. The methods used in these papers were similar, but unfortunately incorrect. Uncertainty was introduced by shifting, in an additive manner, the linear foreign supply and domestic demand curves. Implicitly, they were assuming that the agents were risk neutral or were not aware of the uncertainty since an Expected Utility framework was not used. Their methods also did not consider the impact of
revenues from trade restrictions. In terms of microeconomic theory, they failed to include income effects or implicitly imposed the assumption of a zero income elasticity.

In making comparisons for the large country case, Fishelson and Flatters (1975) concluded that, under conditions of uncertainty stemming from an inelastic foreign supply curve, the flexibility argument no longer favors tariffs. In fact, tariffs appear to be a liability. Pelcovits (1976) compared tariffs and quotas for a small country by limiting imports for non-economic reasons. Quotas were superior to tariffs (above 100 percent) only when uncertainty was attached to the foreign supply curve. However, analyses using import, production, or government revenue constraints are ad-hoc, since the use of such constraints is not justified.\(^1\) A function to measure welfare losses when the economy operates below or above the constraint would be required to account for increasing welfare costs associated with violations of the constraints.

In 1977, Dasgupta and Stiglitz (1977) published a paper comparing tariffs and quotas as revenue raising devices under uncertainty. To facilitate their

\(^1\)This argument is credited to Dr. Harvey Lapan, Department of Economics, Iowa State University.
calculations, they unfortunately used an incorrect approximation in one of their mathematical equations. In using this approximation, they assumed that targeted government revenue was very low. As a result, their conclusion that an ad-valorem tariff dominates a quota holds only under that condition.

Young and Anderson, jointly and separately, have also provided several results on quotas and tariffs under uncertainty. In 1980, they found that a fixed specific tariff is best when the goal of a small country is to limit expected imports. By using a fixed specific tariff, the country can achieve a higher expected consumer surplus. However, if a small country wishes to constrain foreign exchange, a fixed ad-valorem tariff is recommended. On examining revenue-raising trade restrictions, Young (1980) found that the choice of trade restriction depends on the form of uncertainty in the demand and supply functions (i.e., additive or multiplicative), and on the functional forms of supply and demand. As a second best comparison, Young (1982) also compared expenditure quotas versus quotas on the volume of imports when the non-economic objective of the country is to restrict either import expenditures or the volume of imports. His conclusions depended on the elasticity of the demand curve, but, in general, for an elastic demand curve, an expenditure quota is preferred.
Young and Kemp (1982) analyzed different instruments used to achieve optimal stabilization of prices received by domestic producers from international trade agreements. They determined that if the importing country is small, a variable subsidy is the best instrument. In contrast, large countries should use tariffs coupled with either a tax or subsidy (depending on the target price level) for domestic producers. If a country uses either a subsidy or tariff to achieve its goal, the range of target prices for which a variable subsidy is preferred over a variable tariff increases as price uncertainty increases.

During the same time period, Young and Anderson (1982) replaced the expected consumer surplus framework with an expected utility framework that was less restrictive (for elaboration, see Turnovsky, Shalit and Schmitz, 1980; Helms, 1984, 1985; and Choi and Johnson, 1987). By using an expected utility framework, Young and Anderson (1982) were able to demonstrate that tariffs are generally preferred over quotas, with one exception. Quotas may be optimal for small countries that are highly risk averse since they are often heavily dependent on revenues from tariffs or quotas (Prest, 1985). However, the measure of relative risk aversion must be extremely high for a quota to be the preferred instrument.
In a recent attempt to justify the increasing use of non-tariff instruments, Lloyd and Falvey (1986) compared tariff and non-tariff barriers, including quotas, used to protect industry. The primary justification for the use of non-tariff instruments is based on feasibility. Arguments in favor of non-tariff barriers included the transparency argument (which states that non-tariff import barriers are more acceptable because the extent of protection is hidden), the information argument, and the tariff binding argument. Before fixing a tariff rate, the government of a small country should know its domestic demand and supply elasticities. If the country is large, the foreign supply elasticity must also be known. Unfortunately, this information may not be available, or, if available, it may not be reliable. Because of the General Agreement on Trade and Tariffs (G.A.T.T.), the tariff rates on many imports are bound, thus inducing countries to substitute non-tariff barriers (such as voluntary export constraints) for tariffs.

Further arguments in favor of non-tariff instruments, the monopoly rent argument, Bhagwati and Srinivasan's revenue-seeking argument, and Meade's market growth argument, are based on non-equivalence (Lloyd and Falvey, 1986). The first of these advocates that producers prefer quotas because they are valuable property rights (as long
as the quota restricts the allocation of imports among importers). The revenue-seeking argument assumes that tariff revenues can be distributed among groups who would thereby be induced to lobby (perhaps wasting resources that would otherwise be used in production) for those tariffs that would net them a greater share of the revenues. Finally, Meade's argument notes that tariffs allow the quantity of imports to increase if demand increases, while quotas force an upward price adjustment which is judged inferior.

According to Lloyd and Falvey (1986), feasibility and non-equivalence arguments are not convincing enough to explain the growing popularity of non-tariff instruments used for industry protection. By assessing how the different instruments impact the distribution of random prices faced by producers, they were able to rank the instruments from the producers perspective. Since binding quotas set maximum levels for imports that help guarantee minimum domestic prices, risk averse producers will prefer quotas to tariffs that yield the same increase in the average domestic price. Variable levies also yield an optimal distribution by guaranteeing a floor price. More protection is given for the lowest part of the price distribution which is consistent with the fact that the marginal utility of income raises as price falls for
producers with utility functions concave in prices. Using the same rationale, a specific tariff gives more protection at lower prices and will be preferred to an ad-valorem tariff. The opposite results hold when the aim of the government is to improve the welfare of consumer groups given that some protection has to be given to the domestic factors of production.

Optimality of free trade

A question of great and somewhat recent interest for trade theorists was whether or not free trade is still optimal for a small country when uncertainty is present. The answer is no when the central planner is risk averse and makes production and export decisions ex-ante (Jabara and Thompson, 1982). Grossman (1985), unhappy with that conclusion, used a different model to validate the optimality of free trade. Helpman and Razin (1978) arrived at the same verdict when the free trade of goods is accompanied by free trade in equities. The optimality of free trade was also questioned when the quality of traded goods differs and/or is not observable at the time of purchase. The relevant papers on this topic are cited below in the product quality section.
Product Quality

The quality of goods is a variable that appears to have been omitted from much of the modern economic analysis. Strangely enough, classic papers on the economics of smuggling (Bhagwati and Srinivasan, 1973; Bhagwati and Hansen, 1973; and Sheikh, 1974) did not incorporate a quality dimension. The literature on quality is evidently pertinent to the subject of grain quality even though the analysis of grain quality may require new assumptions given the specific nature of the problem.

Commodity characteristics

An early economist to investigate quality was Lancaster (1966, 1971). Lancaster was critical of traditional demand analysis: "A theory that takes no account of information that is readily available [properties of goods], and depends entirely on information that may be available in principle (preference orderings) but not in practice is surely a strange one" (Lancaster, 1971, p. 2). He built a demand analysis framework based on the hypothesis that consumers derive utility from the characteristics ("..."those objective properties of things that are relevant to choice by people" Lancaster (1971, p. 6)) of the goods rather than from the goods themselves. The characteristics are assumed to be measurable,
objective, and the same for all consumers. The demand for the characteristics can be derived by a linear optimization procedure. This approach has been criticized on the ground that the assumptions of linear consumption technology (Lucas, 1975) and the non-negativity of the marginal utility of characteristics (Hendler, 1975) are too restrictive. Another limitation is dependence of the utility on the level of characteristics and not on their distribution among commodities.

A relevant application of the characteristic approach to the grain industry is provided by Veeman (1987). The price for wheat characteristics are estimated using cross-sectional and time series data.

**Regulation**

Product quality has been analyzed in price regulation contexts (e.g., Anderson and Enomoto, 1986; Douglas and Miller, 1974) by studying industrial organization. Anderson and Enomoto (1986) analyzed the short and long run effects of price regulation on factor prices, factor allocation and product quality. Quality is entered as a separately produced intermediate good (e.g., chrome can be used as a quality indicator or as the quality good in car manufacturing). When the regulated price increases, the production of quality increases in the short run and also
in the long run as capital moves toward the regulated sector. Stiglitz (1987) in his survey article, reviewed papers on the relationship of quality and price and showed that when economic agents use the price as a gauge for quality, the demand for factors of production such as labor may be upward sloping. The resulting equilibrium may be characterized by excess supply, contradicting the classical factor price adjustment. Unproductive workers will not find employment even if they are willing to work for a much lower wage.

Stewart (1981), in analyzing uncertain demand in a price-regulated market, employed the same technique as Anderson and Enomoto in the sense that better quality was defined as extra "frills" (e.g., free drinks on airplanes). He made three alternatives assumptions about how the cost associated with the quality variable varies with output (increasing, independent, and decreasing). By maximizing the expected utility of profits, he showed that a risk averse firm provides goods of higher quality than a risk neutral firm. Decreasing absolute risk aversion implies that smaller firms produce goods of better quality than larger firms in this model. It is also shown that if a firm can increase quality by reducing capacity, risk aversion and plant capacity move in opposite direction (e.g., a theater owner may augment quality by providing
more leg-room and in the process reduces his/her theater's number of seats). Stewart (1981) also analyzed the effect of a price reduction on the optimal quality level. It turned out that to conclude in one way or the other, additional restrictive assumptions are required.

Quality, quotas, and tariffs

It was only in 1979 that tariffs and quotas were compared in terms of their effects on quality composition of the goods whose imports are restricted. Falvey (1979) was the first to investigate the effects of import restrictions (quotas, specific and ad-valorem tariffs, and value restrictions) on the quality of imports. In his analysis, which was largely influenced by the work of Borcherding and Silberberg (1978) on transportation costs, Falvey analyzed the effects of trade restrictions on relative prices of two grades of different quality within the same product. Like transportation costs, a specific tariff and a quota change the relative price of the high quality grade which induces a change in the composition of imports in favor of the higher quality variety. It is assumed that the relative prices of the two grades with respect to other products are not important because, as argued by Borcherding and Silberberg (1978, p. 135), two
grades assumed to be close substitutes are presumed to have similar interactions with other commodities.

An ad-valorem tariff was shown to leave the relative price of the two grades unchanged and does not bias the composition of imports in this product category as long as the two grades are imported. The same thing can be said about value restrictions. The above results hold for a competitive exporter as well as for an export monopolist. It is also shown that a voluntary export quota influences the relative price in the same manner as a specific tariff making the cheaper variety relatively more expensive.

Rodriguez (1979) addressed Falvey's topic but used a different approach. He assumed that consumers derive utility from the services provided by the goods and not by the goods themselves. It is assumed that the cost of production is constant for any output level and that the marginal cost increases only when quality is augmented. Output is undeterminate but free entry ensures that no excess profits will be made. The imposition of an ad-valorem tariff is shown not alter the choice of the unit quality content. Total imports of services fall as the price of a unit of services rise in proportion to the tariff.

When a quota on the volume of physical imports is imposed, the exporters still maximize their profits by
equating price to marginal cost. This implies that quality must increase. At this point, the marginal cost does not equal anymore the average cost which means that the average cost of a unit of services has increased. This loss is more than offset by the trade gain or the increase in the amount of services imported. The physical goods imported under a quota are of better quality and yield higher utility than the ones imported under an ad-valorem tariff. As in Falvey (1979), a specific tariff and a quota have similar effect on quality.

If a quality standard is set so that it exceeds the quality level associated with a quota, then it can be shown that the increase in the number of services per unit of physical good and consequently in total services will not be enough to compensate for the loss of revenue or rent that can be generated by a quota. The increase in the average cost then captured by the exporters. When the goal is to restrict the amount of services (the price is then fixed and no more downward sloping), there are no trade gains that can be induced by a quota or quality control as in the previous case. In this case, the higher the price paid to the exporters, the higher the welfare loss. It is easy to show that a quality control is the most inefficient policy to achieve the specified goal. Under the ad-valorem tariff, the exporters receive the free trade price while
under the quota, they receive a higher price since they equalize it to marginal cost which is greater than average cost, the free trade price. The tariff is the preferred instrument even though less physical goods are actually imported!

Bockstael (1984), who was also interested in the effects of quality standards, demonstrated that when consumers can perceive quality ex-ante (e.g., they can see something wrong with grapefruits that look like lemons), minimum quality standards lead to social losses. It is her opinion that quality standards are tools used by protectionists who for political reasons impose quality standards instead of tariffs or quotas.

Santoni and Van Cott (1980) also analyzed the quality adjustment problem linked to the imposition of quotas. As in Rodriguez, they found that quality is upgraded following the imposition of a quota. Their main contribution is that the quality adjustment that takes place when importers are allowed to collude is less than when importers are price takers.

**Voluntary agreements and trade**

Orderly marketing agreements (OMAs) and voluntary export restraints (VERs) are now common instruments in international trade. Both of these instruments place
quantitative restrictions on imports of certain goods but unlike quotas and tariffs, are managed by the exporters. Aw and Roberts (1986) advanced that the OMAs and VERs boost import prices in two ways. The first effect is the one discussed in Falvey (1979) and Rodriguez (1979), that is, OMAs and VERs will lead the exporters to supply goods of higher quality and hence more expensive within a quota-constrained product category. The second effect can be summarized by the tendency for the importing country to divert their import demand toward products from higher-cost non-controlled exporters. Aw and Roberts (1986) used index number techniques to analyze the quality effects of the 1977-1981 OMA on U.S. footwear imports from Taiwan and Korea. They found out that substitution among products within each of their quota categories led to higher prices when an OMA was in effect. In three of their five categories product substitution reduced prices in the non-OMA period. They also discovered that substitution among supplying countries acted to reduce the average price of footwear in the non-OMA years and raise prices when the OMA was in effect.

Helpman and Krugman (1985) claimed that the Hecksher-Ohlin-Samuelson (H-O-S) model fails to explain empirical puzzles such as the volume of trade, the composition of trade, the volume and role of intra-firm trade and direct
foreign investment, and the welfare effects of trade liberalization. The relaxation of the standard assumptions about constant return to scale and perfect competition is the key to their results. Conventional trade theory explains trade by differences in factor endowments (such as labor and capital) between countries. Consequently, one would expect that countries with similar factor endowments would not have a high volume of trade between them. However, in practice nearly half the world's trade consists of trade between industrial countries with relatively similar factor endowments. The theory also suggests that the exports and imports of a country should differ in their factor content. Again, an examination of the real world contradicts this proposition. Industrialized countries are engaged in trade of goods with similar factor contents. However the products differ in quality. West Germany exports expensive cars to the U.S. and imports Chevettes. Note, one way to salvage the Hecksher-Ohlin-Samuelson (H-O-S) model is to change the perception of a country as being a point and allow for regional differences in factor endowments or by assuming that domestic transportation costs exceed international transportation costs as in Melvin's (1985) analysis.

These arguments against the H-O-S model are nothing new. According to Linder (1961), factor proportions
analysis cannot possibly explain intra-regional trade, because by definition, a region has homogeneous factor proportions. He conjectured that intra-regional trade must be explained by reference to other relationships, such as economies of scale and transport costs. His main hypothesis was that countries tend to produce manufacture goods of the quality that were representative of the domestic demand, which in turn is hypothesized to be a function of the average domestic income. Scale economies implicitly restrict the variety of qualities that could be produced within a country, especially for consumers who are on the fringes of the representative demand.

Krugman (1979) formalized one of Linder's arguments and showed that intra-industry trade is likely to take place when there are scale economies internal to the firm. His model has only one factor of production, namely labor and consequently rule out the factor proportions analysis to explain trade. Growth in the labor force and trade yield the same result. In both cases, output for every variety and the number of varieties increase. Factor mobility is hence a perfect substitute for trade as long as the productivity of labor is the same in the two countries engaged in trade.

The pattern of trade is undeterminate and this weakness of Krugman's model motivated Guy Bridgeman to
write a dissertation on the subject. He adopted a larger share of Linder's arguments by trying to capture the effects of scale economies and demand differences between countries. He showed that the distribution of people's willingness to pay for quality within and between countries and the monopolists' ability to discriminate are critical in determining the pattern of trade and the number of varieties that will be produced.

Reputation and quality

Product quality is also captured in models that account for a firm's reputation. In Shapiro's (1983) paper, it is assumed that consumers cannot observe the quality of the goods ex-ante and that the price they pay for the goods is function of the firm's reputation. Reputations take time to build and firms have to sell below cost early in their life cycle. For firms to recuperate their investment in their reputations, the equilibrium market price for quality products has to be above the average cost of production even when the market is competitive. Firms selling low quality items at the price for high quality, eventually get caught and the market price at equilibrium is high enough to prevent firms from "milking" (i.e., being honest for an infinity of periods is just as profitable as being dishonest for a few periods).
What Shapiro did not consider is that the infinite series of profits may be subject to huge variations over time because of changing supply and demand at home and abroad. Also, the length of the series for the honest firms may be uncertain because of political decisions or events that have nothing with normal market forces. Under these conditions, risk averse firms should command higher premiums for producing quality items.

In Allen (1984), a rational-expectations, Nash-equilibrium is used thus making consumers more sophisticated than in Shapiro's model. For example, equilibria characterized by price equal to average cost but above marginal cost are possible. The consumers know the cost functions of the firms and know that firms which would cut their price would have an incentive to produce low quality products. The firms know that the consumers are aware of this and do not reduce their price.

This section of the literature review discussed the modeling of quality and the distinct effects of some trade restrictions when quality is endogenous. Finally, some papers on the reputation of the firm were summarized.

Conclusion

From the literature reviewed in the area of risk and uncertainty, the papers of Baron (1970) and Sandmo (1971)
had the greatest influence on this study. Baron's methodology is used in Chapters Four and Six to analyze quality uncertainty and the effects of price uncertainty on the wheat exporters choice variables. Sandmo's contribution is mostly felt in Chapter Four where his mean-preserving spread technique is used, and in Chapter Five for a discussion on market structure. The work of Falvey (1979), and Young and Anderson (1982) stimulated most my interest for the comparison of trade restrictions under different conditions such as the ones in Chapters Five and Six.

The reputation models were reviewed because of their potential to explain the behavior of U.S. wheat exporters. The reputation of a firm may be country-specific or may depends on the level of diversification of the firm. These reputation schemes are natural developments of Shapiro's original work and will be discussed in more detail in Chapter Five.
CHAPTER THREE: QUALITY VARIABILITY AND CERTAINTY

The results of a model in which import price does not adjust to quality variability are analyzed in this chapter. This situation depicts a problem many importers of U.S. grain have argued they are facing. In this instance, the price of the imported grain (wheat) does not internalize or reflect quality variability. For the system to be efficient, quality fluctuations must be small, centered at the mean, and, likely, but not necessarily, observable at low cost ex-ante. As mentioned in Chapter One, the grades used to identify wheat quality are not precise indicators of all the characteristics the ultimate consumers (foreign buyers) use to make purchase decisions.

The U.S. grading system and the inspection services permit wheat with different characteristics, and, hence, of different quality, to be given the same grade. The final grade given to wheat is the lowest of the characteristics monitored for purposes of ascribing the grade. For example, a bushel of No. 2 wheat scoring at or above tolerance levels for all but one factor necessary to be a

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1Given the manner with which disputes over quality are settled by F.G.I.S., it is possible to have a (imperfect) market in which price does not adjust to small observable quality changes.
No. 1 wheat is sold for the same price as a bushel of No. 2 wheat scoring at No. 2 levels on all factors.

To facilitate the analysis, a simple model for a small country importing a good of variable quality is presumed. The small country assumption is critical to the analysis. If the country can exert enough market power to change the terms of trade by modifying imports, it can influence the grading system of the exporting country. It is assumed that the importing country is a price taker, unable to influence the existing grading system. Effects of quality fluctuations are analyzed under certainty, with the introduction of a quality parameter $q$. This parameter can be interpreted as the 'relative grade' of the imported wheat, implying the grade of the domestically produced wheat is the numeraire. Results of this analysis provide a foundation for evaluating quality effects under uncertainty in Chapter Four.

Even with certainty or the assumption of perfect knowledge, the impact of grain quality on import and domestic production levels for the small price-taking country is not trivial. For example, it is not evident that the volume of imported wheat will increase as quality increases, given the opposite impacts of substitution and income effects. It is shown that the direction of the change in imports of wheat as quality changes, depends on
the size of the import price elasticity. This implies that if the price elasticity of U.S. wheat were smaller than one, export sales would not increase if exporters were to bear a higher cost to raise U.S. wheat quality.

The Structure of the Model

The objective of this section is to elaborate on the structure of the model used to analyze the problem. The model is designed to capture the intricacies of the decision-making of a small country importing wheat of heterogeneous quality. For simplicity, it is assumed that a central planner exists in the importing country, who directly or indirectly (i.e., import quota) controls one or more importing firms. This arrangement is prevalent in many less-developed countries, such as Haiti. The central planner's preferences are complete, reflexive, transitive, continuous, strongly monotonic, and strictly convex, thus guaranteeing the existence of a continuous utility function (Varian, 1984, p. 112). The arguments in the central planner's utility function are the consumption levels of the n different goods available (including wheat) in the importing country, \( U = U(x_1, \ldots, x_n) \).

Heterogeneity in the quality of wheat can be addressed by treating different wheats as different goods or by adding wheats together using a weighting procedure to
account for different grades. Wheats serving distinct purposes should be handled according to the first alternative since they have little in common but their product code. Hedonic models, which do not make distinctions between different grades and different classes, are flawed. The utility function must have more structure when the second alternative is considered. For different grades of wheat to be treated as an aggregated argument in the utility function, the latter must be separable.

The production side of the model has been influenced by Bhagwati and Srinivasan's (1973) model on smuggling. Income is function of the production of only one commodity and can be defined as \( I = Y + G(Y) \), where \( G(Y) \) is the production of another single or aggregate commodity. It is assumed that the first and second partial derivatives of \( G(Y) \) (i.e., \( G_Y \) and \( G_{YY} \)), are both negative. This ensures a concave production possibility frontier. Hence, both commodities are competing for the same scarce inputs. Full employment results from the assumption that the central planner operates on the frontier of the transformation curve. Production adjustments to changes in the quality of the imported wheat are costless and instantaneous.
The Small Country Model and Heterogeneous Quality

The importing country is assumed to maximize the utility function

\[ U(x_1, x_2 + qQ), \]

where \( x_1 \) and \( x_2 \) are the consumption of the domestically produced aggregate good\(^2\) and wheat respectively. The quantity of imported wheat is defined by \( Q \), and \( q \) is the quality adjustment factor that transforms the imported wheat into characteristics or services consistent with those of domestically produced wheat \( x_2 \). For example, a higher \( q \) would be associated with a lower amount of foreign material in the wheat and vice versa. The expected value of \( q \), \( E[q] \), is assumed to equal one, implying that, on average, imported and domestic wheat are identical. It can be assumed either that a one to one relationship exists between the domestic wheat and the services yielded, or that domestic wheat can be used as a numeraire, thus eliminating the need for an additional quality parameter.

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\(^2\)The aggregate good is simply a vector of all the other goods produced in the economy. The underlying assumption is that the production function is separable, used subsequently in two-stage optimization. The allocation of resources within the aggregate good being independent of the real price of wheat, we define the production of the aggregate good as \( G(Y) \).
The utility function is maximized subject to a budget constraint which insures that the value of imports always equals the value of exports,

\[(3-2) \quad P(Y-x_2) + G(Y) - x_1 - Pq = 0,\]

where \(G(Y)\) and \(Y\) denote the domestic production of the aggregate good and domestic wheat, and \(P\) is the relative price of wheat. Finally, \(\phi\) is the Lagrangian multiplier used in the optimization process. The Lagrangian multiplier can be interpreted as the marginal utility of income.

First order conditions with respect to the choice variables of the importing country, namely \(x_1, x_2, Q\) and \(Y\), are expressed in equations (3-3) through (3-7).

\[(3-3) \quad U_1 - \phi = 0,\]
\[(3-4) \quad U_2 - \phi P = 0,\]
\[(3-5) \quad U_2 Q - \phi P = 0,\]
\[(3-6) \quad P + G_Y = 0, \text{ and}\]
\[(3-7) \quad P(Y - x_2 - Q) + G(Y) - x_1 = 0,\]

where \(U_1, U_2, U_{12}, U_{11}, \text{ and } U_{22}\) are the first, cross, and second partial derivatives of the utility function (3-1).

From these first order conditions\(^3\), observe that, when \(q > 1\), the imported wheat is more valuable than domestic wheat. This implies a corner solution with the country

\(^3\text{It is implicitly assumed that the second order conditions for utility maximization are met.}\)
exporting all of its domestic wheat and consuming only imported wheat \((x_2 = 0\) and \(Q = Y + \frac{G(Y) - x_1}{P}\)). When \(q < 1\), a corner solution is also yielded, since the consumers derive less utility from imported wheat than from the domestic wheat \((Q = 0,\) and \(Y = x_2\)). For \(q = 1\), the standard results are observed, where imported and domestic wheat are equivalent in utility to the consumers.

For \(q > 1\), the above discussion makes the questionable assumption that there is sufficient demand for the lower quality domestic wheat that the importing country can export at the import price \(P\) (for the higher quality wheat). This implies either that the importing country can mislead the other countries or that the other countries have different preferences (i.e., different ways of assessing \(q\), based on differences in the grading systems of the exporting and importing countries).

The first alternative incorporates the premise that there is a signal extraction problem\(^4\), and it may be more or less realistic. The second explanation rests on the supposition that tastes and preferences vary among countries, perhaps due to culture and education. Intra-commodity trade, the simultaneous importing and exporting

\(^4\)The countries interested in the importing country's domestic wheat are not aware that intra-commodity trade is occurring. This situation may arise in free trade zones, for example.
of what is apparently the same product, is common and has
been well documented in the literature (Helpman and
Krugman, 1985). However, since most countries buying
primary products like wheat use them for the same purposes
(feed, milling, and baking) and theoretically have access
to the same technology, they are all likely to value the
same characteristics.

For this reason, we impose the assumption of
homogeneity in tastes and preferences among countries. A
good whose quality is perceived as inferior in one country
will also be perceived as inferior in the other countries.
This does not rule-out intra-commodity trade per se, but
rules-out the exporting of low-quality wheat at the high
quality price. For the present analysis, the domestic
production of wheat is always entirely consumed
domestically, \( Y = x_2 \). On this condition, the utility
maximization problem can be simplified,

\[
U(x_1, Y + qG) + \phi [G(Y) - x_1 - PQ].
\]

The corresponding first order conditions differ somewhat
from those in equations (3-3) through (3-7). Specifically,

\[ U_1 - \phi = 0, \]
\[ U_2 + \phi G_Y = 0, \]
\[ U_2 q - \phi P = 0, \] and
\[ G(Y) - x_1 - PQ = 0. \]
From (3-9) and (3-10), $U_2/U_1 = -G_y$, or the domestic marginal rate of substitution equals the domestic rate of transformation. Similarly, from (3-9) and (3-11), $U_2q/U_1 = P$ or the marginal rate of substitution of imported wheat for the aggregate good is equal to the relative price. Finally, from the ratio of equations (3-10) and (3-11), we obtain an equality between the domestic rate of transformation and the world price weighted by the quality adjustment factor, $-G_y = P/q$.

If consumers are capable of discerning quality variations, domestic production will adjust, and hence change the real price $P/q$. Even if the price of the imported wheat does not change, some adjustment will occur through the price of the domestic wheat. For example, if the quality of the imported wheat deteriorates ($q < 1$), the value of the domestic wheat will appreciate and its relative price will reflect the quality differential. As long as the buyers can discriminate among goods of different quality, there is no market failure. The adjustment that takes place does not matter, whether through the domestic price or through the import price, since the relative prices remain the same. This result holds only when the agents in the importing country know the quality of the imported and domestically produced wheat and can react instantaneously to quality change.
For the second order conditions of the utility maximization problem (3-8) to hold, the sign of the determinants of the border-preserving principal minors of the bordered Hessian matrix must alternate in sign (Varian, 1984). Totally differentiating the above first order conditions and constructing the bordered Hessian matrix yields,

\[
\begin{bmatrix}
U_{11} & U_{12} & U_{12}Q & -1 \\
U_{21} & U_{22} + qG_x & U_{22}q & G_y \\
U_{21}q & U_{22}q & -p & 0 \\
-1 & qG_y & -p & 0 \\
\end{bmatrix}
\begin{bmatrix}
\frac{dx}{1} \\
\frac{dy}{1} \\
\frac{dp}{1} \\
\frac{dq}{1} \\
\end{bmatrix}
= \begin{bmatrix}
0 \\
0 \\
0 \\
0 \\
\end{bmatrix}
+ \begin{bmatrix}
-U_{12}q \\
-U_{22}q \\
-U_{22}qq - U_2 \\
\end{bmatrix}
\begin{bmatrix}
dq \\
dp \\
\end{bmatrix}
\]

The notation makes extensive use of subscripts which denote partial derivatives, unless stated otherwise. For example, \(U_{11}\) represents the second partial derivative of the utility function with respect to the consumption level of the aggregate good, \(x_1\). Domestic or imported wheat, adjusted for quality differential, form the second argument in the utility function. The subscript '2' denotes a derivative with respect to wheat. The usual assumptions on the signs of \(U_{11}\) and \(U_{22}\) are made (i.e., \(U_{jj} < 0\) for \(j = 1\) or \(2\)). This implies that utility is increasing at a decreasing rate as the consumption of wheat or the aggregate good increases. Barring saturation, the marginal utilities from the consumption of the aggregate good and from wheat are positive. By using results from the first order conditions
and rearranging the terms, we obtain the following expression for the determinant of $A$.

Since $G_{YY} < 0$, the expression

$$|A| = -P^2 G_{YY} U_{11} + 2P q G_{YY} U_{12} - q G_{YY} q^2 U_{22}$$

is unconditionally negative when $U_{12} > 0$ and will be negative if $(-p U_{11}/q, -q U_{22}/P) > -U_{12}$, when $U_{12} < 0$. The expression for the determinant of the $3\times 3$ minor,

$$\begin{vmatrix}
U_{11} & U_{12} \\
U^2_{21} & U_{22} + q G_{YY} G_Y \\
-1 & G_Y
\end{vmatrix} = -[U_{11} G_Y^2 + 2U_{12} G_Y + U_{22} + q G_{YY}] > 0,$$

is clearly positive when the above condition for $U_{12}$ hold, thus guaranteeing that the second order conditions are met.

Price and Quality Change

The comparative statics for the model developed in Section 3 are revealing. Of principal interest is how the volume of imports and the consumption and production of domestically produced goods are affected by changes in the price and quality of imported wheat. These results are summarized below.

(3-13) $dQ/dP = \left[ -q U_{11} G_Y^2 - 2q U_{12} G_Y - q U_{22} - q G_{YY} + q U_{12} q G_{YY} - q U_{11} q G_{YY} \right]/|A| < 0.

(3-14) $dY/dP = \left[ -q U_{11} P G_Y - 2q U_{12} P + q U_{22} q \right]/|A| > 0.

(3-15) $dx_1/dP = \left[ q P G_Y - q G_{YY} q U_{12} + QU_{22} q^2 G_{YY} \right]/|A| > < 0.$
(3-16) \( \frac{dQ}{dq} = 2U_2U_{12}G_Y + U_2U_{22} + U_2U_{11}G_Y^2 - \$U_{12}QG_{YY} + \$U_{22}QG_{YY} + \$U_2G_{YY} \geq 0 \) or \( \leq 0 \).

(3-17) \( \frac{dY}{dq} = \frac{[-U_2g(U_{12}G_Y + U_{22})]}{|A|} < 0. \)

(3-18) \( \frac{dx_1}{dq} = [P*G_{YY}(P_1U_{12}Q - U_{22}Q_2 - U_2)] \geq 0 \)

As expected, equation (3-13) shows that as the price of imported wheat increases, the substitution and income effects move in the same direction, and demand for imported wheat decreases. Equation (3-14) shows that an increase in the price of imported wheat will increase the domestic production of wheat, if the quality of imported wheat is held constant. When the price of imported wheat rises, the domestic producers of wheat augment their production and the consumers substitute the domestic wheat for the imported wheat.

The result from equation (3-15) is, as anticipated, ambiguous since the substitution and the income effects move the demand for the aggregate good in opposite directions. A relatively higher price for domestic wheat induces the domestic producers to produce less of the aggregate good, and the consumers to consume more of it.

The three results from equations (3-13) through (3-15) are standard and can be found in most textbooks (e.g., Varian, 1984). The remaining results are interesting,
since quality is not a characteristic for which extensive comparative statics analysis exists. It is particularly important to note that equation (3-16) is ambiguous. Can equation (3-16) be interpreted as a contradiction of Samuelson's proposition that more is always preferred to less (Samuelson, 1983; Varian, 1984)? The answer is simple. It is possible for an importing country to reduce the volume of imported wheat and still be maximizing utility depending on preferences and on the extent to which quality can compensate for quantity. When \( q \) (the quality variable) increases, fewer units of imported wheat are needed to achieve the same level of utility. In addition, decreasing marginal utility may result in the consumption of fewer units of imported wheat, and higher consumption of the aggregate good. The importing country, therefore, may achieve greater utility from purchasing a lower volume of wheat.

Equation (3-17) demonstrates that when the quality of imported wheat increases, the demand for domestic wheat falls. The necessary condition for signing equation (3-16) can be derived by first rewriting the utility function as

\[
U = U(G(Y) - \delta \theta, Y + \theta),
\]

where \( \delta = \frac{P}{q} \) and \( \theta = qQ \). Note, \( \frac{dQ}{dP} = \frac{[d(\theta/q)/d\delta]}{q^2} \), therefore, equation (3-16) can be expressed as
(3-16') \[ \frac{dQ}{dq} = \frac{d(\theta/q)}{d\delta} \frac{d\delta}{dq} 1/q - \theta/q \]
\[ = \left[ \frac{d\theta/d\delta}{d\delta} (-\frac{P}{q}) - \theta \right]/q^2 \]
\[ = (e_Q - 1)Q/q. \]

The sign of (3-16) is hence positive if and only if
(3-20) \(-e_Q > 1\).

Thus, it is obvious that (3-16') is positive, if the price elasticity of \(Q\), defined as \(-P/Q(dQ/dP)\), exceeds one.

An alternative and more tedious approach uses the unambiguous sign of equation (3-17) to determine under what condition higher quality of imports will result in increased imports. Equation (3-16) can then be rewritten.
(3-16'') \[ \frac{dQ}{dq} = \left[ (dQ/dP)(P/Q)(-Q/q) \right] + |A|(-Q/q)/|A|. \]

This is equivalent to the condition expressed in (3-16), and to take a positive value, again condition (3-20) \(-e_Q > 1\) must hold. Intuitively, an increase in \(q\) can be treated as an increase in the real price of domestic wheat \(P/q\), also the price of the imported wheat when the latter is expressed in terms of the grade of the domestic wheat.

Hence, the sign of (3-16') depends whether the demand for wheat is elastic or inelastic.

Recently, this result as shown in (3-20) was obtained by Murphy (1980) who used a characteristic model with exogenous income. Equation (3-16'') is identical to his equation (11) and is rather tedious to derive. The alternative proof given in (3-16') is derived in a much
more intuitive and straightforward manner by taking into account the definition of $\delta$ ($P$ and $q$ are symmetric).

Murphy's objective was to identify the relationship between quality and consumer demand. He demonstrated that the parameterization of quality in a demand equation could lead to erroneous results since an assumption has to be made about the effect of quality on demand.

The result obtained in (3-20) is very important. If the price elasticity of imported wheat from the U.S. was smaller than one, it could not be hypothesized that the decrease in the volume of U.S. wheat exports is attributable to lower wheat quality. However this is unlikely since firms with market power (like U.S. wheat exporters) will try to operate in the elastic portion of the demand curve.

The result implied by equation (3-18) can be rationalized by the same argument used for evaluating equation (3-16). When the quality of imported wheat improves, the production and consumption of domestic wheat decrease. This implies that the domestic production of the aggregate good, $G(Y)$, increases if the country remains on the production possibility frontier. This increase in the production of the aggregate good can be used to increase domestic consumption or to increase exports which, in turn, will be traded for more high-quality imported wheat. Total
FIGURE 3-1. The effects of an increase in the quality of imported wheat on production and consumption
consumption of wheat, as deduced from (3-18) or from (3-16) and (3-17) is ambiguous relative to quality. If equation (3-16) is positive, (3-18) will be negative and vice versa.

Figure 3-1 illustrates the effect of an increase in the quality of imported wheat on both domestic production and the volume of imports. Initially, domestic and imported wheats are identical in quality, and production and consumption of wheat are indicated by $P_0$ and $Q_0$. When the quality of imported wheat increases, domestic production falls to $P_1$, while consumption of physical units of wheat falls to $Q_1$. The volume of imported wheat characteristics has risen from $Q_0$ to $q_1$, enabling the importing country to achieve a higher level of utility. The change in import volume is in general ambiguous, and depends on the curvature of the production possibility frontier and preferences. The number of physical units of wheat consumed may decrease, but the number of wheat characteristics consumed is likely to increase. The strong monotonicity assumption is not violated because utility is defined in terms of characteristics, not physical units. One should note that differences in expressing imports in terms characteristics or in terms of physical units are reconciled when imports are measured in terms of exports ($P_1^* - Q_1^*$).
Results in this section may explain trends in data on U.S. wheat imports for Brazil, Japan, U.S.S.R., Chile, Ecuador, and Portugal, all of which have complained in the past about the quality of U.S. wheat. In general, these countries have decreased their dependency on U.S. wheat by obtaining a higher proportion of imported wheat from other countries and/or by increasing domestic production. Figure 3-2 shows U.S. wheat imports as a percentage of total wheat imports between 1965 and 1986 for these six countries. Decreases in the percentage of U.S. wheat imports are especially marked in Brazil, U.S.S.R., and Portugal. Chile had roughly a 20 percent decrease of U.S. wheat as a percentage of their total wheat imports, while Japan and Ecuador had a relatively constant share of U.S. wheat imports.

Figure 3-3 illustrates the relative volume of U.S. wheat imports with respect to domestic production between 1965 and 1986 in the these countries. In 1977, Japan imported 15 times more wheat from the U.S. than it produced. In 1986, that percentage had decreased by more than three fold. The proportion of U.S. wheat imports as a share of domestic production in Brazil grew steadily between 1978 and 1984; however, it dropped suddenly in 1985 and approached zero in 1986. The series for Portugal and
FIGURE 3-2. U.S. wheat as a percentage of total imported wheat
FIGURE 3-2. (Continued)
FIGURE 3-3. U.S. wheat as a percentage of domestic production
FIGURE 3-3. (Continued)
Chile began to converge toward zero in the early 1980s, and by 1986 had fallen to zero.

Welfare Effects of Quality Change

The welfare effects of quality changes can be evaluated more conveniently using the indirect utility function. From the indirect utility function, the Marshallian demand for wheat can be easily derived. Equation (3-7) can be rewritten as

\[ \text{Max. } U(x_1, Y + \theta) + \frac{1}{q}(G(Y) - x_1 - \delta \theta). \]

Note that since utility is in services that consumers derive, it makes sense to express all the arguments in this form. The domestic consumption of the aggregate good, \( x_1 \), and of domestic wheat, \( Y \), yield one unit of aggregate and wheat services, respectively. The services derived from imported wheat, \( \theta \), depend entirely on the value of the quality parameter \( q \) and the volume of imported wheat \( Q \), since \( \theta = qQ \). A higher \( q \) implies that a larger quantity of services are derived from a unit of imported wheat. The price of imported wheat services, \( \delta \), is simply \( P/q \), so that the budget constraint remains the same as in equation (3-8) (i.e., \( PQ = \delta \theta \)).

Let \( X_2 = Y + \theta \) be the total consumption of wheat services or characteristics. By maximizing (3-21) for the choice variables, \( x_1, Y, \) and \( \theta \), we obtain the first order
conditions found in (3-9) through (3-12). Notice that q is no longer a parameter, since it does not appear (individually) in the utility function, nor the budget constraint. As well, q is not a separate argument in the implied demand functions. The only parameter appearing in the demand functions is δ, defined as P/q. This is why the impact of changes in quality can be expressed as multiple of the impact of changes in price as shown by (3-20). From the first order conditions for (3-21), \(-G_Y(Y) = \delta\) is derived. The domestic production of the imported good wheat, Y, can then be expressed in terms of δ.

Using equations (3-8) and (3-10), θ can be expressed in terms of \(x_1\) and δ, \(θ = θ(x_1, δ)\). By inserting \(θ(x_1, δ)\) into the budget constraint, \(I = G(Y) + δY = x_1 + δx_2\), \(x_1\) can be obtained in terms of δ. The same procedure can be used for the remaining variables, \(θ = θ(δ, I(δ))\) and \(Y = Y(δ, I(δ))\).

Now if these expressions are inserted into the direct utility function (3-21),

\[
(3-22) \ U[\theta(δ, I(δ)), Y(δ, I(δ)) + θ(δ, I(δ))] = V[δ]
\]

is obtained.

The first derivative of the indirect utility function (3-22) with respect to the parameter δ is

\[
(3-23) \ \frac{dV}{dδ} = V_δ + V_IY = -V_Iθ,
\]
since by Roy's identity, \( V_5 = -V_I X_2 \), where \( X_2 = Y + \theta \).

Equation (3-23) provides valuable information about fluctuations in welfare resulting from changes in the real relative price (quality) of imports. The sign of (3-23) indicates that an increase in the real relative price of wheat services will lower welfare. This is intuitive since the country is a net importer of these services. The demand for imported services from equation (3-23) is similar to one obtained by Woodland (1980), and confirms the usefulness of Roy's identity when income is endogenous.

Woodland's indirect trade utility function expresses the maximum level of utility a trading nation can attain, assuming the existence of a direct community utility function, as a function of a vector of prices for commodities, a vector of factor endowments and the balance of trade. In the above analysis, factor endowments were omitted and a market clearing condition has been imposed, rendering the balance of trade component redundant. The novelty in (3-22) is that quality change has been introduced with relative ease into a model with endogenous income.

Equations (3-24) and (3-25) describe effects of augmenting the quality parameter and the price of imports on welfare,

\[ (3-24) \frac{dV}{dq} = \delta V_I \theta / q, \text{ and} \]
In equation (3-24), welfare increases when the quality of the imported good is augmented. Of course, these ameliorations are not beneficial to all the groups in society. But, overall welfare is improved, assuming that the gainers can appropriately compensate the losers. In a way, the case of \( q > 1 \) can be interpreted as dumping (because \( P \) is not allowed to adjust). The appropriate response from the importing country is to thank the exporter. Equation (3-24) could have been derived from the direct utility function (3-7), where \( \frac{dU}{dq} = U_2Q \) is identical to (3-24), since from the first order conditions \( U_2 = \delta = V_1 \delta \) and \( Q = \delta / q \). Equation (3-25) shows that a jump in the price of imported wheat, holding \( q \) constant, will hurt the domestic consumers more that it will help the domestic producers of wheat.

Indeed all the above welfare statements are made in the context described in the second section of this chapter. If a domestic factor market was introduced, some of the results derived above would not hold if some of the factor were product specific. An increase in \( q \) would not necessarily make the country better off. It follows that in such a situation, trade restrictions may dominate free trade. If nothing precludes the movement along the transformation curve, free trade is optimal and an increase
in quality will improve welfare. Let $\delta^*$ and $P^*$ be the world prices for imported wheat services and imported wheat respectively. The domestic prices are as before given by $\delta$ and $P$. The difference resides in the fact that these prices are now function of the amount of characteristics on the market and on world prices. If a quota or tariff is imposed the income of the importing country can be represented by: $I = G(Y) + \delta Y + (\delta - \delta^*) \theta$.

The following equation determines the optimal volume of imported wheat.

\[
(3-26) \quad \frac{dV}{dQ} = \left( -V_1 x_2 + V_1 (Y + \theta) \right) \left( \frac{d\delta}{dP} \frac{dP}{d(\theta g^{-1})} + qV_1 (\delta - \delta^*) \right)
\]

\[
= V_1 (P - P^*) = 0.
\]

Because the marginal utility of income is always positive, an optimal solution is reached when the domestic price equals the world price.

Conclusion and Implication

The model provided a basis for assessing the impact of changes in quality, while keeping the level of complexity to a minimum. The main result is the link between import response to a change in quality and the price elasticity of the imported good. Given a price elastic import demand, imports will decrease when the quality of the imported product deteriorates.
Because the export of U.S. wheat has significantly decreased during recent years, one can hypothesize from these results that a quality problem exists in the wheat export industry in the U.S. As emphasized in Chapter One, the quality of U.S. wheat may or may not have met contract specifications. The economics of the question go beyond legal dimensions, since the importers' expectations and evaluations of imported wheat determine the value of the quality parameter $q$.

It is evident that the behavior of U.S. exporters depends on the importing country's ability to measure quality. Consequently, there must be an optimal scheme for quality adulteration that will keep importers from improving their inspection services, and, at the same time, will lower the costs of the exporters. The optimal scheme should also take into account the behavior of competitors. It is conceivable that if there is a leader in the industry, all major exporters might lower their wheat quality if the leader did so. Perhaps the U.S. grain quality problem results from the fact that no U.S. firm can emerge as a leader given the structure of the U.S. grain export industry. This argument will be investigated in Chapter Five.
CHAPTER FOUR: SELF-SUFFICIENCY AND QUALITY UNCERTAINTY

It was previously shown that for a small country producing two goods, demand for the imported good (wheat) does not necessarily increase with increased quality. Assuming utility maximizing behavior under certainty, the rate of transformation \((-G_Y)\) and the marginal rate of substitution \((U_2/U_1)\) were found equal to \(P/q\), where \(P\) is the price of imported wheat, \(q\) is the quality parameter for the imported wheat and \(P/q\) can be interpreted as the price of domestic wheat adjusted for quality of imported wheat under certainty. It was also confirmed that an increase in the quality of the imported good (wheat) was potentially welfare improving, irrespective of the response of the import schedule to changes in the quality parameter.\(^1\) Distribution issues were excluded from the analysis. However, assuming the existence of a social welfare function, it is easy to conceive that the new equilibrium may not be superior in the absence of an efficient compensation scheme.

From these results we hypothesized that the decline in U.S. wheat exports during the 1980s was perhaps in part due

\(^1\)Even if the importing country does not adjust its domestic production and import schedule as the quality of imported wheat improves, it will be better off than before, but not as well off as if it were reacting to the changing environment. This is akin to Le Chatelier's principle.
to an inefficient marketing strategy focusing too much on the numerator and not enough on the denominator of the relevant parameter $P/q$. The U.S. grain marketing system, as discussed previously may not provide sufficient incentives to improve export grain quality. The above results indicate some consequences from being uncompetitive in terms of quality. During Congressional Hearings, the grain export industry defended its practices, arguing that the blending of the grain is very accurate, rendering virtually impossible any systematic bias (United States House of Representatives, 1986a). What if the industry's claim were true? Would that put an abrupt end to interest in quality of exports? No, the stochastic nature of the quality parameter, discussed in the description of the grading system and inspection services, forces risk averse wheat importers to be concerned about higher moments of the quality distribution. Again, the final certificate system determining quality at the point of export forces the importers to bear the risk of significant wheat deterioration during transit. Since the grading system is based on the lowest scoring factor, there is a strong potential for quality heterogeneity within a grade.

\[2\text{Again, this abstracts from the legal aspects of quality. A valid inspection certificate could hardly be used as a proxy for the relative quality of U.S. wheat with respect to wheat of different origin.}\]
Moreover, because some important characteristics cannot be measured yet by F.G.I.S., there is genuine uncertainty about the scores on these factors. The rounding of the dockage was a major quality problem in the past. Today, the measure appearing on the certificate is closer to the true level of dockage. However, for importers, uncertainty about the representativeness of the sampling procedure continues to discredit the gain in measurement accuracy.

In the short-run, the true quality not being fully observable is almost irrelevant in determining the price of wheat. The key factor is importers expectations of quality. Good behavior by exporting firms is not immediately rewarded except when the firm has an established reputation. Chapter Five will hopefully shed some light on this point.

It can be hypothesized that, on average, the quality of U.S. wheat is equal to the quality of wheat for competing exporters, and that the major quality problem of U.S. exporters is quality consistency. The behavior of a risk averse, small country importer purchasing wheat of uncertain quality is now investigated. The direct utility function approach used in Chapter Three is well-suited for the analysis under uncertainty. The corresponding indirect utility function derived in Chapter Three is of little value since the argument $\delta (\delta = P/q)$ is unobservable and
cannot be verified by the importers under uncertainty. The usual convenient properties of the indirect utility function unfortunately do not hold in this situation.

It will be shown that under reasonable conditions, uncertain import quality induces the small country to become more self-sufficient. The marginal impact of uncertainty on the importing country's demand for imports and domestic production will be discussed. These results can be interpreted as a partial explanation of the lower import demand for U.S. grain experienced since 1980.

Quality Uncertainty

It was shown that the direct utility maximization problem (3-8) for the importing country can be rearranged in the more tractable form represented by (3-19). The first argument in (4-1) is the consumption of the domestically produced aggregate good. Because the budget is always in equilibrium, it is equal to the domestic production of the aggregate good minus the value of imports. The second argument consists of the number of wheat characteristics consumed in the importing country. Maximizing the expected value of this expression over domestic wheat $Y$ and the volume of imported wheat $Q$, we obtain

(4-1) $\max_{E_q} \{U[G(Y)\cdot P - Q, Y + qQ]\}$. 
The first order conditions, for the maximization problem are

\((4-2)\) \(E(U_1 G_2 + U_2) = 0\), and

\((4-3)\) \(E(-U_1 P + U_2 q) = 0\),

where \(U_1\) and \(U_2\) are the marginal utility of the first and second argument, \(G_2\) is the negative of the marginal rate of transformation and \(q\) is the random quality variable. From equation \((4-2)\), it is apparent that the domestic rate of transformation \((-G_2 = E[U_2]/E[U_1])\) is not equal to the expected value of the marginal rate of substitution \(E[U_2/U_1]\) anymore. This is the first contrast between the utility maximizing behavior under certainty and uncertainty. Also, the second first order condition \((4-3)\) for the certainty problem can be rewritten

\((4-4)\) \(E[U_1 P] = E[U_2]E[q] + \text{cov}[U_2, q] = 0\),

where \(E\) is the expectation operator and \(\text{cov}\) the covariance between two terms. The covariance term on the right hand side is clearly negative since \(dU_2/dq = U_{22} < 0\). Then it follows that

\((4-5)\) \(-G_2 = P/E[q] - \text{cov}[U_2, q]/E[U_1]E[q] > P/E[q]\).

It is clear from equation \((4-5)\) that uncertainty about the quality of imported wheat will drive up the domestic rate of transformation (or expected price of the domestic wheat), assumed to be of stable, known quality. Domestic wheat adjust to the uncertainty in the quality of imported
wheat because its quality is known with certainty. Since
the impacts of an increase and a decrease in $q$ of the same
magnitude will not offset each other (given the concavity
of the utility function), domestically produced goods of
stable, known quality in this model, are valued more highly
ex-ante. The increment in the expected price of the
domestic wheat is related to the concept of risk premium
developed by Pratt (1964). An important difference lies in
the nature of the arguments of the utility function.
Unlike Pratt's utility function which was increasing in
wealth, the utility function represented in (4-1) is
function of goods and services. The risk premium as
defined by Pratt (1964, p. 125) is equal to one half times
the variance of an actuarially neutral risky source of
revenue times the measure of absolute risk aversion ($-\frac{U''}{U'}$). The risk premium is usually a measure of risk
expressed in terms of cash. Because of the dimensions of
this problem, it would be expressed in terms of
characteristics.

This risk premium notion is compatible with the
production processes of food processing industries. Wheat
can be seen as an intermediate good whose quality has to be
above a certain level to prevent partial or total loss in
the production of the final goods (e.g., bad flour can ruin
Figure 4-1. The effect of quality uncertainty on production and import of wheat
In such instances, the buyer may be concerned by the higher moments of the distribution of quality, as well as by the mean. Figure 4-1 illustrates the effect of quality uncertainty on domestic production and consumers choices. Uncertainty induces domestic wheat production to increase ($P_0$ to $P_1$) and wheat imports to decrease ($P_0 Q_0$ to $P_1 Q_1$), resulting in a higher degree of self-sufficiency.

It is assumed in Figure 4-1 that $q$ still equals one. This need not be the case since $q$ can fluctuate around one implying that the real price of imported wheat remains $P$. A decrease in $q$ would result in a lower level of utility as indicated by $U_1'$. 

**Quality Uncertainty and Protectionism**

Is quality uncertainty a case for protectionism? Consumer knowledge of the variability of the quality of imported wheat and the exclusion of other factors leading to market failure preclude market intervention by government. However, the presence of asymmetry of information (consumers not being able to discriminate foreign from domestic wheat) makes a strong case for a tariff. The tariff could potentially increase welfare but would not be a first best policy (Bond, 1984). A tariff (positive or negative) would have the effect of adjusting the consumption and production of domestic wheat to levels
closer to what they would be if the consumers were fully aware of quality variability. However, a tariff would penalize domestic consumers by having them pay a similar price for both imported and domestic wheat. The first best policy is to differentiate the products in the eyes of the consumers by informing them about the variability in quality. Then, consumers with different reactions to the variability in quality can maximize their utility.

If the consumers in the importing countries cannot discriminate quality, trade may allow goods of inferior quality to enter the domestic market and lower the average quality of the products available. Domestic producers would lose from trade since the domestic price would be lower due to trade and this price would be insensitive to fluctuations in the quality of the imported wheat. The key issues are whether the consumers can discriminate wheat of different origins, and if so, how long it will take for them to learn about the variability of quality. In some cases the first best policy may not be feasible. The costs associated with grading, inspecting, labelling and diffusion of information designed to hasten consumer

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3 The need for identical quality standards and marketing regulations was voiced during free trade negotiations between the U.S. and Canada. If consumers have the ability to quickly learn about quality variability, a unique set of rules would constitute a redundant investment.
learning processes may be prohibitive. A tariff could then be seen as a practical solution to improve welfare.

The problem analyzed here is similar to the one evaluated by Bond (1984), where consumers cannot discriminate the imported low quality products from the high quality domestic goods. In our case, the domestic and imported goods have the same expected or average quality but the quality of the imported good is allowed to vary.

Marginal Impacts of Quality Uncertainty

Uncertainty about the quality of imported wheat induces the importing country to increase the production of domestic wheat. This can be regarded as what Sandmo (1971) called the overall impact of uncertainty on domestic production. In this section, the effect of a 'marginal' change in quality uncertainty will be investigated. The objective is to discover whether the domestic production of wheat is increasing, decreasing, or constant when the quality of the imported wheat becomes more uncertain (through a mean-preserving spread of the quality distribution). Also of interest is the marginal impact of quality uncertainty on imports.

In the previous section, it was implicitly assumed that the second order conditions were satisfied. The current analysis will begin by more closely evaluating the
second order conditions. The first step is to differentiate equations (4-2) and (4-3) with respect to $Y$ and $Q$. The resulting equations can then be stacked in matrix form and the conditions under which the sign of the determinant will be positive can be determined. The corresponding matrix is

\[
\begin{bmatrix}
E[U_{11}G_Y^2 + U_{12}G_Y + U_{22}] & E[-U_{11}PG_Y + U_{22}q + U_{12}G_Yq - U_{12}P] \\
E[-U_{11}PG_Y + U_{22}q + U_{12}G_Yq - U_{12}P] & E[U_{11}P^2 - 2U_{12}Pq + U_{22}q^2]
\end{bmatrix}
\]

Before proceeding, some of the terms in (4-6) must be rewritten to facilitate the analysis. (Recall that $E[q] = 1$.)

\begin{align*}
(4-7) \quad & E[U_{22}q] = E[U_{22}] + \text{cov}[U_{22}, q], \quad \text{with } \text{cov}[U_{22}, q] > 0. \\
(4-8) \quad & E[U_{12}G_Yq] = E[U_{12}]G_Y + \text{cov}[U_{12}G_Y, q], \quad \text{cov}[U_{12}G_Y, q] > 0. \\
(4-9) \quad & E[U_{12}Pq] = E[U_{12}]P + \text{cov}[U_{12}P, q], \quad \text{cov}[U_{12}P, q] > 0. < 0.
\end{align*}

Assuming a positive marginal utility from the consumption of both the aggregate good and wheat ($U_1$ and $U_2 > 0$) and that $U_{11}$, $U_{22}$, $G_Y$ and $G_{YY}$ are negative, we can find the determinant of (4-6) (Appendix, Table A-1). Note that $E[q^2] = 1 + \sigma_q^2$, where $\sigma_q$ is the variance of $q$. Sufficient conditions for this determinant to be positive are that $U_{11}P \leq U_{22} \leq U_{12}G_Y$ (which implies $U_{11}U_{22} \geq U_{12}^2$), $G_Y\text{cov}(U_{12}, q) \approx \text{cov}(U_{22}, q)$, $E[U_{12}q]$, $E[U_{22}q] < 0$ when $U_{12} <
0, and \( \text{cov}(U_{12}, q) > 0 \). In other words, the degree of substitutability between wheat and the aggregate good has to be limited for an interior solution to exist. When \( U_{12} > 0 \) and \( \text{cov}(U_{12}, q) < 0 \), sufficient conditions are \( \text{E}[U_{12}q] > 0, \text{E}[U_{22}q] < 0, U_{11}p \leq U_{22} \leq U_{12}g, \) and \( 2U_{12}(g_p + p) < \text{cov}(U_{12}, q) \). The magnitude of complementarity must also be limited, as does the negative effect of uncertainty on complementarity. It is also assumed that \( U_{22}q + \text{cov}(U_{22}, q^2) < 0, \) regardless of the sign of \( U_{12} \).

We can now proceed to analyze the effect of a marginal increase in uncertainty on the volume of imports, 'Q', and on the domestic level of production 'Y'. To accomplish this task, let the random variable \( q \) be defined as follows (Sandmo, 1971):

\[
(4-10) \quad \text{E}[q] = \text{E}[\tau q + \Omega].
\]

To preserve the mean of the distribution of \( q \) when stretched, the expected value of \( q \) should remain the same.

\[
(4-11) \quad \mu d\tau + d\Omega = 0 \quad \text{or} \quad d\Omega/d\tau = -\mu,
\]

where \( \mu \) is defined as the mean of \( q \) and is set to one.

The first order conditions can now be differentiated with respect to \( \tau \), and, by applying Cramer's rule, \( dQ/d\tau \) can be obtained. Since the determinant of the Hessian matrix is positive, the sign of \( dQ/d\tau \) is given by the sign of the determinant below.
To make any inferences about the sign of the determinant, the terms on the right hand side must be rewritten as
\[
\begin{array}{c}
(\tilde{\mathbf{a}}_0 - \tilde{\mathbf{a}}_2) \tilde{\mathbf{z}}^T \tilde{\mathbf{a}}_1 \\
(\tilde{\mathbf{a}}_2 - \tilde{\mathbf{a}}_0) \tilde{\mathbf{a}}_1 \tilde{\mathbf{z}}^T \\
\end{array}
\]

(4-12)

Note that from the second order conditions when \( \tilde{\mathbf{z}}^T \tilde{\mathbf{a}}_1 \tilde{\mathbf{a}}_2 > 0 \), the terms in the upper right corner of (4-12) can be expressed as
\[
(\tilde{\mathbf{a}}_2 - \tilde{\mathbf{a}}_0) \tilde{\mathbf{a}}_1 \tilde{\mathbf{z}}^T \tilde{\mathbf{a}}_2 \\
(\tilde{\mathbf{a}}_0 - \tilde{\mathbf{a}}_2) \tilde{\mathbf{a}}_1 \tilde{\mathbf{z}}^T \\
\]

(4-13)

Note that from the second order conditions when \( \tilde{\mathbf{z}}^T \tilde{\mathbf{a}}_2 < 0 \), the terms in the upper right corner of (4-12) must be compared to the terms on the right hand side of the equation:
\[
(\tilde{\mathbf{a}}_2 - \tilde{\mathbf{a}}_0) \tilde{\mathbf{a}}_1 \tilde{\mathbf{z}}^T \tilde{\mathbf{a}}_2 \\
(\tilde{\mathbf{a}}_0 - \tilde{\mathbf{a}}_2) \tilde{\mathbf{a}}_1 \tilde{\mathbf{z}}^T \\
\]

(4-14)

The terms in the upper right corner of (4-12) can be expressed as
\[
(\tilde{\mathbf{a}}_2 - \tilde{\mathbf{a}}_0) \tilde{\mathbf{a}}_1 \tilde{\mathbf{z}}^T \tilde{\mathbf{a}}_2 \\
(\tilde{\mathbf{a}}_0 - \tilde{\mathbf{a}}_2) \tilde{\mathbf{a}}_1 \tilde{\mathbf{z}}^T \\
\]

(4-15)

The terms in the upper right corner of (4-12) can be expressed as
\[
(\tilde{\mathbf{a}}_2 - \tilde{\mathbf{a}}_0) \tilde{\mathbf{a}}_1 \tilde{\mathbf{z}}^T \tilde{\mathbf{a}}_2 \\
(\tilde{\mathbf{a}}_0 - \tilde{\mathbf{a}}_2) \tilde{\mathbf{a}}_1 \tilde{\mathbf{z}}^T \\
\]

(4-16)

The terms in the upper right corner of (4-12) can be expressed as
\[
(\tilde{\mathbf{a}}_2 - \tilde{\mathbf{a}}_0) \tilde{\mathbf{a}}_1 \tilde{\mathbf{z}}^T \tilde{\mathbf{a}}_2 \\
(\tilde{\mathbf{a}}_0 - \tilde{\mathbf{a}}_2) \tilde{\mathbf{a}}_1 \tilde{\mathbf{z}}^T \\
\]

(4-17)

The terms in the upper right corner of (4-12) can be expressed as
\[
(\tilde{\mathbf{a}}_2 - \tilde{\mathbf{a}}_0) \tilde{\mathbf{a}}_1 \tilde{\mathbf{z}}^T \tilde{\mathbf{a}}_2 \\
(\tilde{\mathbf{a}}_0 - \tilde{\mathbf{a}}_2) \tilde{\mathbf{a}}_1 \tilde{\mathbf{z}}^T \\
\]

(4-18)

The terms in the upper right corner of (4-12) can be expressed as
\[
(\tilde{\mathbf{a}}_2 - \tilde{\mathbf{a}}_0) \tilde{\mathbf{a}}_1 \tilde{\mathbf{z}}^T \tilde{\mathbf{a}}_2 \\
(\tilde{\mathbf{a}}_0 - \tilde{\mathbf{a}}_2) \tilde{\mathbf{a}}_1 \tilde{\mathbf{z}}^T \\
\]

(4-19)
The above expression is positive when $U_{12} < 0$ and $\text{cov}(U_{12}, q) > 0$, and ambiguous when the signs of $U_{12}$ and $\text{cov}(U_{12}, q)$ are positive and negative respectively. In the latter case, a small covariance term implies a positive sign. In light of the signs obtained from equations (4-13) and (4-14), (4-12) is negative when $U_{12} < 0$ or when $U_{12} > 0$ and (4-14) $\geq 0$. When wheat and the aggregate good are substitutes, uncertainty induces a rise in domestic production of wheat (domestic wheat is substituted for imported wheat) and a decline in the production of the aggregate good. Less of the aggregate good means smaller export potential, and, consequently, smaller imports given the budget constraint used in (3-8). However, as substitutability increases, the effect of uncertainty on production is not as pronounced since wheat is more "replaceable". It follows that the variations in production of domestic wheat and imports of wheat will be smaller the higher the degree of substitutability. This is consistent with the fact that consumption decisions are made ex-post. When $U_{12} > 0$, the production of domestic wheat increases to ensure that enough wheat characteristics will be available to complement the volume of aggregate good produced. The production of the aggregate good declines, thus reducing the import capacity of the country. The higher the degree of complementarity, the sharper the
decline in the production of the aggregate good and the lower the volume of imports. In general, the higher the degree of substitutability, the smaller the changes in production and imports following a marginal increase in uncertainty. (4-12) can be expanded as,

\[-[U_{22}q^2 + Q\text{cov}(U_{22}, q^2)][U_{11}G_Y^2 + 2U_{12}G_Y + U_{22} + U_1G_{YY}] + U_{22}Q\]

\[-\text{cov}(U_{22}, q) - \text{cov}(U_2, q)Q^{-1} - U_{12}\text{cov}(U_2, q)G_Y + [\text{cov}(U_{12}, q)PQ - \text{cov}(U_2, q) - \text{cov}(U_{22}, q)Q][U_1G_{YY} + U_{22} + U_{12}G_Y] - U_{12}[\text{cov}(U_{12}, q)G_Y^2 + \text{cov}(U_{22}, q)] + [G_Y\text{cov}(U_{12}, q) + \text{cov}(U_{22}, q)]^2.\]

From the second order conditions, \((U_{22}q^2 + \text{cov}(U_{22}, q^2)) < 0\) and the \(\text{cov}(U_{12})\) is small especially when \(U_{12} > 0\). The above expression, \(dQ/d\tau\), is clearly negative despite the apparent ambiguity in (4-12). This ambiguity vanishes immediately if one imposes a quadratic functional form for the utility function. A quadratic functional form does not have as many indirect or covariant effects being only twice differentiable and will nullify (4-13). In general, it can be concluded that under reasonable conditions, it is possible to infer that the movement in the volume of imports is inversely related to quality uncertainty. A grading system, coupled with inspection services and a fair dispute settlement mechanism, each designed to reduce quality uncertainty, should positively influence the volume of U.S. exports. The rounding of dockage to the nearest 0.10 percent, instead of to the nearest 0.50 percent, will
surely positively affect U.S. exports. Dockage is an important characteristic for a buyer. It has been the source of substantial quality uncertainty, and may have contributed largely to the decline in exports between 1981 and 1986.

The sign of \( \frac{dY}{dT} \) can be determined by the sign of the determinant represented by (4-15).

\[
\begin{vmatrix}
-\text{cov}(U_{12}G_Yq,q) - \text{cov}(U_{22}q,2) & E[-U_{11}G_Yp - U_{12}P + U_{12}G_Yq + U_{22}q] \\
\text{cov}(U_{12}Pq,q) - E[U_{22}q(q-7)^2] & E[U_{11}P^2] - 2\{E[U_{12}P]E[q] \\
- \text{cov}(U_{22}q,q) - \text{cov}(U_2,q) & + \text{cov}(U_{12}P,q) + E[U_{22}q^2]
\end{vmatrix}
\]

As in the previous case, the expression in the upper left quadrant is equal to zero when \( U_{12} < 0 \), while the upper and lower right quadrants contain terms which, when summed, are negative. The sum of the terms in the lower left quadrant are clearly positive when \( U_{12} < 0 \) and ambiguous otherwise. It follows that the sign of the determinant is positive when \( U_{12} < 0 \) and if \( \text{cov}(U_{12},q) \) is small when \( U_{12} > 0 \). The determinant is expanded in the Appendix (Table A-2). If one was willing to assume (for simplicity) that the form of the utility function is quadratic, then the sign of \( \frac{dY}{dT} \) would clearly be positive. If this were the case, it could be concluded that a marginal increase in quality uncertainty induces an
augmentation in the domestic production of wheat. An increase in the substitutability of wheat and the aggregate good still implies \( \frac{dY}{dT} > 0 \), but the increase will be smaller given the higher demand for the aggregate good.

Canada is currently debating the costs and benefits of introducing triple-m wheat varieties. These high yielding, lower quality varieties are unfortunately difficult to discriminate from the traditional lower yielding, high quality Marquis wheat. The introduction of triple-m wheat would give Canada the opportunity to blend medium and high quality wheat and would increase the risk of contamination (involuntary blending). Importers would legitimately expect a higher degree of quality uncertainty and would try to be more self-sufficient. Indeed, the importers reactions depend on the substitutability between imported and domestic wheats.

**Conclusion and Application**

In this chapter, it has been demonstrated that uncertainty about the quality of imported wheat induces the importing country to achieve a higher level of self-sufficiency in wheat supply. Factors which can lower the level of uncertainty should be considered by the U.S. grain export industry to aid in regaining the export markets it has lost.
Quality uncertainty is not in itself an argument for protectionism for an importer. Trade barriers are justified only if the economic agents in the importing country are unable or slow in learning about the variability in the quality of imported wheat. Informing the public or creating an environment that would ease the 'learning process' (e.g., labeling by the country of origin) are instruments superior to tariffs and quotas in this instance. However, less developed countries may prefer to impose a tariff because of their limited capability for establishing quality and disseminating information.

Though other exporters were not included in the model, this is not as damaging as one might think. The importers who buy wheat from the U.S. do so for economic and/or political reasons. U.S. wheat is perhaps the only imported wheat they can buy or afford due to these non-market factors. It is estimated that the U.S. subsidizes from 50 to 80 percent of its wheat exports. Increasing their domestic production may be the only way to substitute for U.S. wheat under quality uncertainty. If the importer's choice of a supplier is politically motivated, an economic

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4This range was provided by experts working in the Center for Agricultural and Rural Development at Iowa State University. The U.S.D.A. considers this to be a 'sensitive' issue.
model including many exporters would be redundant. For importers who must purchase imported wheat of variable quality, the only alternative is to move toward self-sufficiency.
CHAPTER FIVE: REPUTATION AND QUALITY

As mentioned in Chapter One, the wheat export market is dominated by five major exporting countries, the U.S., Canada, Australia, France, and Argentina. The structure of the U.S. wheat export industry differs significantly from that in Canada and Australia, where government agencies are responsible for marketing wheat exports. In the U.S., wheat is exported by a small number of private corporations, such as Union Equity, Cargill, Continental, Bungi, and Koch. The only government involvement is in the weighing, grading and inspection of wheat.

Wheat is a very heterogeneous product. To discover its true quality, a buyer must invest in an inspection service. Because the cost of obtaining timely and accurate information about quality is rising rapidly along with the level of accuracy, the buyer may not have full information about wheat quality when ownership is transferred. When an importing country purchases grain, it takes into consideration what it knows about an exporting firm's reliability in supplying grain that meets quality expectations. Sometimes importers may not have all the information necessary to make an optimal purchase decision; however, it can be assumed that they efficiently use the information at hand to make a judgment about the reputation
of an exporter relative to the quality of the import. Exporters, in turn, know that reputation is important to importing countries, and are assumed to take economic advantage of this knowledge.

This chapter analyzes different reputation schemes in an attempt to rationalize what Carl Shapiro (1983) has termed the "milking of a reputation". Two broad approaches are used to model reputation. First, the reputation of the firm is determined by a weighted average taking into account an estimate of the quality supplied by the firm and the average quality of grain supplied by all exporting firms in the country. Because of the costs involved in determining quality, the importer's estimate of wheat quality is not perfectly accurate. The reputation of the country as a wheat exporter is then used to complement the importer's set of information about quality. Such a reputation scheme can also be rationalized on grounds that government agencies are heavily involved in the world export market for wheat and that as a result, wheat is discriminated on the basis of origin regardless of the market structure for exported wheat that prevails in the exporting countries. This signal extraction problem appears to induce exporting firms to behave as free-riders', especially when the weight on the country's reputation is large.
A second broad approach assumes that the importer has firm-specific historical information about quality supplied, but, perhaps because of an inadequate inspection system, the information about current quality is available with a lag. Thus, an exporting firm must sell high quality products at low quality prices until it has established a positive reputation with the importing country.

Reputation and Country-Specific Information

This section begins with an analysis of the U.S. wheat export market. The reactions of the remaining world to changes in the U.S. export market are initially assumed to be exogenous. This micro approach facilitates an analysis of the implications for the market structure of the U.S. wheat export industry. The number of firms appears to affect the quality and quantity of exported wheat. It is assumed that there are n firms in the U.S., and N in the world. The subscripts j and i are firm- and country-specific.

In this section, a firm's reputation for grain quality is determined by the reputation \( R_i \) of all exporting firms in the country from which it operates and by the importer's estimate of the quality supplied by the firm \( q_j \). Both \( R_i \) and \( q_j \) are used to discover the true quality of imported
wheat, \( q^* \). Specifically, \( q_j = q^* + \epsilon_j \), while \( R_i = q^* + \epsilon_i + \phi \). The \( \epsilon \)'s denote the sampling error associated with obtaining the information and \( \phi \) accounts for the noise caused by the quality supplied by other firms in country \( i \). It is assumed that the \( \epsilon \)'s have an expected value of zero. The weight on the country's reputation can then be derived as

\[
a = \frac{\sigma_{\epsilon_j} + \text{cov}(\epsilon_j, \epsilon_i) + \text{cov}(\epsilon_j, \phi)}{\sigma_{\epsilon_j} + \sigma_{\epsilon_i} + \sigma_{\phi} + E[\phi^2]}
\]

Indeed this general expression can be simplified without loss of generality by presuming that the covariance terms and \( E[\phi^2] \) equal zero. Country \( i \) is assumed to be a major exporter with market power. Reputation is denoted by \( R \) and firm \( j \)'s profit can then be expressed as

\[
\pi_j = P(Sq_kQ_k)[R]Q_j - C(q_j, Q_j)q_jQ_j,
\]

where \( R = aR_i + (1-a)q_j \), \( R_i = \Sigma q_iQ_i/Q_i^T \), and \( Q_i^T = \Sigma Q_i \). The quality expected from firm \( j \) by the importer depends partially on the quality supplied by all the firms in country \( i \), and not solely on the quality supplied by firm \( j \). \( \Sigma q_kQ_k \) is the sum over \( N \) exporting firms, and, therefore, represents the total supply of grain.

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1An alternative way of looking at the problem is to have the importer take two samples of imported wheat. A first sample would be taken as wheat is unloaded from a ship. The wheat would then be stored in a bin containing wheat of the same grade from the same country of origin. A second sample would then be taken.
The environments determining the export price of wheat supplied by firm j on the world market. \( q_j \) and \( Q_j \) denote quality and quantity supplied by firm j, and the product, \( q_j Q_j \), can be interpreted as the number of characteristics supplied by firm j. \( C \) reflects the cost of supplying a wheat characteristic given the existing technology. The dimensions of the problem are illustrated in Figure 5-1. The price received by firm j depends on country i's reputation and the volume of characteristics supplied by the remaining world.

The first order conditions with respect to \( Q_j \) and \( q_j \) for this maximization problem are

\[
\begin{align*}
(5-2) \quad PR &+ P_q q_j Q_j R + P_a \left[ (q_j/Q_j^T) - (R_i/Q_i^T) \right] - C q_j - C_q q_j Q_j = 0, \\
(5-3) \quad P_q Q_j R + P(1-a+\alpha Q_j/Q_j^T) Q_j - C Q_j - C_q Q_j q_j = 0.
\end{align*}
\]
$P_\theta$ is the derivative of $P$ and $Q$ with respect to the specific characteristics determining the market price.

All firms from country $i$ have access to the same markets and, consequently, face the same demand for their products. They also pay the same price for their inputs in terms of characteristics and are assumed to behave in a similar manner. Because of this symmetry, the subscripts can be dropped and the equations rewritten. This implies that reputation is equal to quality ($R = q$), and that price can be written $P = P(nq + \Sigma q_j Q_j)$, with the summation going from $n+1$ to $N$. An individual firm's market share of the total volume of wheat exported from country $i$ is equal to $1/n$ ($Q_j/Q^T = 1/n$).

(5-4) $Pq + P_\theta q^2 Q - Cq - C_q Q = 0$.
(5-5) $P(1-a+a/n)Q + P_\theta Q^2 - CQ - C_q Q = 0$.

The term $P(1-a+a/n)Q$ in (5-5) can be interpreted as a firm's marginal revenue from improving the reputation of the country by increasing the quality of the export product (wheat) while holding volume constant.

In this model, a firm does not receive the full benefit of the improved reputation since it shares the benefit with $n-1$ other firms in its country. This is obvious when looking at the difference between $C_q Q$ and $C_q q$. The gap between $C_q Q$ and $C_q q$ is non-existent at $a=0$, but becomes positive as the importance of the country's
reputation ($R_i$) rises. This implies that quality is lower when $a > 0$. A similar model (DM model) was developed by Donnenfeld and Mayer (1987). The present model differs from the DM model in three basic ways. First, in the current model, firms are assumed to have market power. This is perhaps more descriptive of the U.S. grain export industry. Secondly, the labor market present in the DM model has been omitted and a grain input market included. Since U.S. agriculture is not labor intensive, analyzing the effect of different governmental regulations on prices received by farmer's (grain inputs) is more important than analyzing the labor market. Finally, and most importantly, the use of the country-specific reputation is rationalized. Our model is more general, and appears to be more realistic, since the case in which reputation depends entirely on the country's reputation is a special occurrence.

The first order conditions given by (5-4) and (5-5) indicate that export firms have strong incentives to behave as free-riders by supplying lower quality wheat to the market. Since each firm assumes that the remaining $n-1$ firms will maintain the country's reputation, they will supply wheat of lower quality and still expect to receive a price for a higher quality wheat. If all $n$ firms behave in this Cournot-Nash fashion, they will all become free-riders
and quickly lower or destroy the reputation of the exporting country.

While the costs of this behavior are shared by all n firms in country i, individual firms suffer greater losses from their free-rider behavior when there are few exporting firms in the country. In contrast, profits from maintaining higher quality standards, and thus a good reputation, increase when n decreases and a exceeds 0. It is hypothesized that by reducing the number of exporting firms, country i can improve its reputation; however, other constraints could be utilized to force exporting firms to supply wheat of higher quality. Country i should also be concerned with its ability to take advantage of its market power (Johnson's optimal tariff argument), as well as with factor prices since the welfare of farmers appears to be politically important.

Quality and number of firms

For this model, comparative statics can be used to determine the consequences of increasing the number of exporting firms that exhibit free-rider behavior. Equation (5-6) shows how the number of exporters will affect the quality of wheat exports.

\[ \frac{dq}{dn} = \frac{1}{|A|} \left[ -GDq/n + GaPQ/n^2 - ECQq + DCQq^2/n - aPCQqQ/n^2 - ECQQqQ + DCQQq^2Q/n - aPCQQqQ^2/n^2 - EDq^2/Q^2 \right] \]
\[ +EC_{qq}^2 < 0. \]

Assuming that the second order conditions hold, \( D \), the determinant of the Hessian matrix, will be positive. The quality of wheat supplied by all firms will decrease as the number of exporting firms increases, assuming that the demand for characteristics is convex. The implication of a convex demand is that the price of a 'wheat characteristic' will decrease (increase) at a decreasing (increasing) rate as the volume of characteristics offered increases (decreases). Convexity would not hold if a kinked demand curve had been assumed. It can be hypothesized that firms in the wheat export industry operate in the flatter portion of the demand curve. This implies that a small increase in price would be unprofitable. Therefore, rather than raise prices, exporters prefer to lower quality in an attempt to increase profits because they realize that importing countries often have inadequate inspection services. The convexity assumption is critical to a similar conclusion drawn from the DM model. The reputation of a country can be improved by decreasing the number of exporting firms. When an importer's expectations for quality are country-specific, a competitive market structure (i.e., a large number of exporting firms) is not optimal since every exporter is likely to exhibit free-rider behavior. It
follows that $dQ/dn$ is more negative as 'a' gets closer to one and when n is large.

Comparative statics can also be used to analyze what effect an increase in the total number of exporting firms will have on the output of an individual firm. To determine this effect,

\begin{equation}
(5-7) \quad dQ/dn = \frac{1}{|A|} \left[ -EDq/Q-EC_qq-EC_{qq}q^2+EC_{QQ}qQ-BaPq/n^2+ \right.
\left. aPC_qqQ^2/n^2-BP_q(a-a/n)qQ+P\sigma C_{QQ}(a-a/n)q^2Q^3 \right] > = < 0.
\end{equation}

When a=0, $dQ/dn < 0$. However, when $a \approx 1$, $dQ/dn$ is ambiguous, as it may be more profitable to lower the supply of wheat characteristics by considerably lowering q and increasing Q. Again, this stems from the fact that firm j expects the other firms to maintain the country's reputation. It is then possible for the volume of wheat supplied by firm j to decrease as the number of firms decreases.

This contradicts a similar result from the DM model. The contradiction develops from the assumption that the exporting firms have market power, that a large number of firms are present, and that the weight of the country's reputation in R is large. Decreasing quantity leads to less influence in establishing the country's reputation, and, hence, to smaller returns from supplying high quality services. On the other hand, the increase in price due to
a decrease in quantity may more than compensate for the firm's weaker role in determining the country's reputation. An increase in the weight of the country's reputation in \( R \) will adversely influence quality and induce an increase in quantity as shown below.

\[
dq/da = 1/|A| \left[ G - C_q q - C_q q Q \right] (1 - 1/n)
\]
\[
dQ/da = 1/|A| \left[ Bq/q - C_q q Q \right] (1 - 1/n)
\]

Other things being equal, reducing the number of exporting firms from country \( i \) will induce the remaining firms to upgrade quality and reduce or increase the volume of exports. A smaller number of exporting firms will, therefore, improve the reputation of all firms from country \( i \). What, then, is the optimal number of firms? From the firm's point of view, one is an optimal number since each firm could not only receive full returns from maintaining the reputation of the country, but could also exercise market power (in the factor and output market) without concern for 'domestic free-riders'. If this were to occur, farmers might be damaged because fewer firms in country \( i \) implies both a lower price and a lower export volume, assuming that demand and supply from other exporting countries remains constant.

Since the well-being of farmers is a primary concern of policy makers in industrialized countries, it is important to develop a market structure that considers, and
perhaps maximizes, the welfare of grain producers. Presence of only one firm could create an optimal market structure for farmers if the profits of the monopsonist exporting firm were subject to a 100 percent tax. In this way, country i would extract maximum profits from the rest of the world. Those profits would then be distributed 'costlessly' to farmers such that they obtain the same profit margin they would have received from marketing their own grain in the most efficient manner.

In practice, a 100 percent tax on profits would reduce the incentives of private firms to maintain a good reputation. If an exporter's short-run gains from falsely marketing low quality goods as prime quality goods becomes detrimental to the reputation of the country, then taxing the exporting firm's profits at a rate of 100 percent would not be optimal for farmers. The solution to this potential conflict of interest is to lower the tax rate or the establishment of a governmental agency like the Canadian Wheat Board, a Crown corporation, chartered to act in the farmer's best interest. Presence of this public Board, as opposed to private firms, might explain why Canada's reputation for wheat exports is better than that of the U.S.

U.S. wheat producers have organized an exporting firm (Union Equity) to compete with private exporting firms. In
organizing this firm, U.S. wheat producers hoped to make the factor market more competitive. Ruling out collusion, the addition of this firm does not optimize quality and aggregate quantity. However, if Union Equity was to be the leader of the industry, the end result would be similar to the one that would be obtained by a monopolist government agency.

Export quota

The U.S. could potentially benefit from decreasing the number of private exporting firms (through licensing), but this may not be politically feasible. Alternatively, restricting the output of exporters via an export quota or tariff might lead to an improvement in the U.S. reputation for export quality. Until recently, however, the effect of quotas on quality has not been critically examined. While the maximization problem remains the same, the choice variables over which optimization is carried out is reduced to one. The first order condition is given by (5-5) since $Q$ is exogenously determined. Differentiating (5-5), solutions for the variables of interest can be obtained. When a quota is imposed, the change in the quality of the product can be expressed as,

\[
(5-10) \quad -\frac{dq}{dQ} = \frac{[P_\theta qQ(1+n-an+a)+P_\theta nq^2Q^2-C_qqQ-C_{qq}Q^2]}{P_\theta Q^2} \left[ (1+n-an+a)+P_\theta qQ^3-2C_qQ-C_{qq}Q \right] > 0.
\]
A binding quota on a specific firm's output will increase the quality of its output. This concurs with the findings of the DM model, and with the literature on voluntary export restrictions. A quota, which obviously has the intended effect on the level of output, also increases the quality of the output. Intuitively, this model being a characteristic model in which q can be substituted for Q (though marginal production costs of increasing q and Q may differ), a higher q has to compensate for the lower Q.

It can be shown that a specific tariff will have the same effect as the quota in this model, which necessarily imply that a lower volume and higher quality follow the imposition of a specific tariff. An ad-valorem tariff will decrease the volume of wheat exported and will have an ambiguous effect on quality. This may seem paradoxical especially when considering that in this context, an ad-valorem tariff is just like a tax on both q and Q. One would expect them both to decrease. Again, different cost structures can be assumed and using more q and less Q may be seen as a less expensive alternative of supplying wheat characteristics at a lower price.
Minimum quality standards

Binding quality standards specified in (5-5) as \( q \), will have the same effect as quotas (i.e., increasing quality and lowering output). Maximizing (5-5) over the output level \( Q \) (assuming \( q \) is fixed) and differentiating the resulting first order condition leads to this conclusion.

\[
(5-11) \quad \frac{dQ}{dq} = -\left[ PeqQ(1+n)+P\theta nq^2 Q^2-C_q q-C_{qq}q^2 \right]/Peq^2(1+n)
+P\theta nq^3 Q-2C_q q-C_{qq}q^2 < 0.
\]

Quality standards move quality and quantity in consistent directions, and are, therefore, just as efficient as quotas or licensing.

Unfortunately, these policies are not equivalent from a practical standpoint. Historically, enforcement of quality controls has been less than successful. False grades and weights have been relatively common in the grain industry (Ek, 1985). Given that licensing and quality standards yield the same result, the preferred policy is the one that can be enforced with the least effort. Policies that attempt to force a (country-based) behavior on an individual firm have not been and will not be successful. The case of one firm with its profits being taxed dominates the scenario with many firms constrained by a specific export tariff and/or a quality standard.
The market failure in this case is that the reputation of the firm is country-specific. The best way to remedy to the situation is to directly internalize the source of the market failure. When there is only one firm in the exporting country, there is no market failure since the reputation is firm-specific and there is no need for an optimal tariff.

The reputation mechanism used above enables us to conjecture that the decline in the quality of U.S. wheat exports in the early 1980s may have been the result of the adoption of new hybrids. Many of these new hybrids were more difficult to discriminate, and, therefore, required better technology to maintain efficient grading and inspection services. Importers with obsolete technology and those who were unwilling to pay more for inspection and grading services relied more heavily on the exporting country's reputation.

**Foreign competition and quality**

The previous comparative statics exercises assumed that output from major foreign exporters is constant. In reality, firm j has to deal with the free-rider problem at both the domestic and international level. If the rest of the world increases the supply of wheat when firms from country i exercise their market power, then it is clearly
not optimal for firm $j$ to reduce output unless it has the welfare of foreign firms in its utility function. This argument has been advanced quite often by critics of U.S. agricultural supply management programs.

Countries in economic associations, such as the European Economic Community (E.E.C.), may also face the free-rider problem if the reputation of each country is association-specific. This may partially explain why France is the only major wheat exporter in the E.E.C. While disputes over pricing often contribute to the death of an economic cartel, quality may also be an underlying factor. When quality is difficult to assess, free-riders will lower their own product quality, inducing a drop in the profits of other cartel members unaware of the quality problem. Cartel members, whose profits are falling, have incentive to leave the cartel to increase their volume.

Even if foreign firms had the same technology and were facing the same market conditions as the U.S., they would not produce the same quality of wheat because the number of firms in these countries differs. The fact that some countries have wheat boards responsible for wheat exports may have profound implications for the structure of the industry in the U.S. The free-rider problem does not exist in these countries, and, even if they had the same technology and faced the same market conditions as the
U.S., they would supply wheat of higher quality than U.S. exporters.

If one of these boards were sophisticated and large enough to determine the reaction functions of its rivals and then base its decisions on these reactions, it would emerge as a leader despite the larger market share of the U.S. Because of their lack of unity, U.S. exporters would be followers, and the U.S. would not operate in an optimal fashion given its share of the world market. If this were true, it would be beneficial for U.S. wheat exporters to collude in an effort to exercise the country's market power. Legally, this strategy is precluded by anti-trust laws. The first best policy would be to either remove the anti-trust laws, reduce the number of exporting firms, or impose enforceable restrictions on their behavior. For political or practical reasons, these alternatives cannot be fully implemented.

Perhaps U.S. wheat exporters do collude to some extent, and the lower quality of U.S. wheat exports reflects the use of their market power (q being their instrument). The fact that Australia and Canada are

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\(^2\)This is a good argument against anti-trust laws in the U.S.
competitive in terms of quality could be perceived as a symptom of a Stackelberg disequilibrium situation. The U.S. cartel may have been challenged by foreign firms trying to establish themselves as market leaders. If this were true, the response of the U.S. cartel would be to increase quality and decrease prices to force the foreign firms to return to their role as followers. The turning point may have occurred in 1986, when U.S. exports began to rise again (Figure 1-1). The high number of quality complaints in 1986 and 1987 may have been a bargaining strategy used by importers or may have been the result of continuing pressure on individual U.S. firms to be free-riders. Once again, the number of U.S. firms is critical.

Reputation of an Individual Firm

If the reputation scheme were not country-specific, why would an exporting firm risk losing market share for short-run gains? In this section, the focus is on firms with a reputation that is a function of lagged quality supplied. As before, the cost of obtaining timely and accurate quality information is prohibitive, thus an importer is forced to use reputation in making purchasing decisions. The actual discovery of imported wheat quality

3 Even as followers, Canada and Australia are expected to supply wheat of higher quality given the difference in the farmers' wheat productions function in these countries.
is lagged (n periods), and exporting firms can easily substitute lower quality wheat under this condition. Incentives for a firm to 'milk' its reputation are analyzed in the following subsection.

Reputation and lagged quality information

From Shapiro (1983), asymmetry of information enables reputation to be defined as a function of the quality supplied n periods previously,

\[
R_t = q_{t-n}.
\]

This implies that it takes n periods for a firm to establish a reputation. During the first n periods, the importer does not trust the exporting firm. They assume that a lower quality wheat that 'appears' to meet contract specification will be supplied, and will be willing to pay the price for the lower quality \(q_0\) wheat. Suppose, for example, that a firm is selling a U.S. No. 1 wheat to a new buyer. Assume further that U.S. No. 1 and No. 2 wheats appear similar, while U.S. No. 3 is easily recognizable. When purchasing U.S. No. 1 wheat in the first n periods, the new buyer will negotiate to pay the price for U.S. No. 2 wheat instead of the price of the higher quality No. 1. Since substituting a U.S. No. 3 wheat for a U.S. No. 1 would be readily detected, this would not be attempted by a rational exporter.
It is obvious that if a firm is to milk its reputation, it must do so after investing in a reputation, since no profits can be made until the firm has established a reputation. It is then reasonable for importers to consider the alternative behaviors of an established exporting firm when determining a price or policy that should prevent the firm from behaving erratically. The price must be high enough for the firm to recover its investment in a reputation and low enough not to generate excessive profits that would induce new exporting firms to enter the market. In this case, the exporters are using what Koutsoyiannis (1983) calls a 'limit-pricing strategy'. The exporters have market power, but are unable to use it due to uncertainty about provoking a massive entry of new firms (or countries) in the market. If the limit-pricing assumption seems unrealistic in this circumstance, an oligopolistic structure may be hypothesized. If there was a barrier to entry, the equilibrium price would be between the minimum price required to induce oligopolists to remain ethical and the price that would prevail if importers had full information. Asymmetry of information erodes the market power of exporters because it is more difficult for exporters to differentiate the quality of their product in the eyes of importers. In practice, factors exogenous to the model cause some exporting firms to establish better
reputations in a shorter time period than others, and hence these firms will not attempt to increase the flow of information to consumers. For simplicity, limit-pricing is assumed in the derivation of the results.

If the firm behaves consistently (supplying quality \( q \)), it will receive the following compensation on a per unit basis:

\[
(5-13) \quad \pi = [p(q) - c(q)][1 + (1/1+r) + (1/1+r)^2 + \ldots + (1/1+r)^\infty]
\]

\[
= [p(q) - c(q)](1+r)/r,
\]

where \( p \) is the price established exporters receive for supplying wheat of quality \( q \). The cost of a unit of quality \( q \) wheat is represented by \( c(q) \). Profits are discounted at rate \( r \), reflecting the opportunity cost of capital. Profits under a quality inconsistency scenario are given by equation (5-14).

\[
(5-14) \quad \pi = [p(q) - c(q_0)][1 + (1/1+r) + \ldots + (1/1+r)^{n-1}]
\]

\[
= ([p(q) - c(q_0)](1+r)/r)[1-1/r(1+r)^{n-1}].
\]

For \( n-1 \) periods, the firm can substitute lower quality grain (\( q_0 \), the lowest possible quality that can be substituted for higher quality wheat), at a price corresponding to higher quality \( q \). Then, in the \( n^{th} \) period, the substitution is detected. Per unit costs of grain of a given quality are denoted by \( c \), and are increasing in \( q \). Using (5-13) and (5-14) and solving for \( p(q) \) we obtain Shapiro's (1983) result:
(5-15) \( p(q) = c(q) + \left[ (1+r)^n - 1 \right] \left[ c(q) - c(q_0) \right] \).

The importer will not buy wheat of quality \( q \) at a lower price than indicated by (5-15) because under such circumstances, the exporting firm would supply grain of lower quality.

**Length of information lag**

Equation (5-15) depicts an equilibrium with price exceeding average cost. The net present value of the profits equals the necessary investment to establish a reputation. If the equilibrium price is the one given by equation (5-15), why would a firm 'milk' its reputation? Two hypotheses will be discussed. First, future output prices and therefore profits may be uncertain. Assume that \( R = q_{t-1} \), or that an exporter can substitute lower quality grain for only one period before it is detected. If profits are uncertain, the firms will compare \( EU[p(q) - c(q)](1+r)/r \) to \( U[p(q) - c(q_0)] \). A risk neutral firm will supply grain of quality \( q \) at price \( p(q) = c(q) + r[c(q) - c(q_0)] \), while a risk averse firm would require a higher monetary incentive to remain quality consistent. The risk

---

4Let the expected net present value of supplying \( q \) when \( p \) is uncertain be \( NPV_q = E[\pi + \pi(1+r)^{-1} + \ldots + \pi(1+r)^{-n}] \). This is equal to the net present value of supplying wheat of quality \( q_0 \), \( NPV_{q_0} = \pi + c(q) - c(q_0) \). Then, \( U(NPV_q) \leq U(NPV_{q_0}) \) by concavity of the utility function in \( \pi \). The strict equality holding for risk neutral exporters.
neutral firm will force the risk averse firms out of the market since the latter will prefer to make a 'fast buck' with certainty rather than earning a series of variable profits with the same expected net present value. This subject was first discussed by Sandmo (1971).

What if all the firms involved in grain exports have the same attitude toward risk? Would this imply that they command the same risk premium to sell output of consistent quality? Assuming that exporting firms from various countries have comparable risk attitudes, some of them could be expected to behave differently. Time preferences and the level of risk\(^5\) may vary from one exporter to another. Because different time preferences is akin to different attitude toward risk, the focus of our attention will be centered on the second factor. The exporters may face the same price uncertainty but have to deal with what could be called higher political risk.\(^6\) The effect of political risk is translated into a possible shorter series

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\(^5\)As documented in the literature on the Allais paradox, the attitude of the firm toward risk may change depending on the alternatives confronted by the firm. However, such a possibility is ruled out in our analysis.

\(^6\)The term political risk was chosen because trade barriers, in the absence of market failure, can only be justified by political motives. The (economic) argument for strategic trade barriers is not strong in a world in which trade partners would not hesitate to retaliate which seems to be the case in the real world.
of profit when the firm tries to maintain a reputation. The expected profit associated with a consistent behavior is given by equation (5-16).

\[ \pi = aA + (1-a)A[1-(1/(1+r)^n)] \]

where \( A = \frac{[p(q)-c(q)](1+r)}{r} \) and \( (1-a) \) is the probability that the infinite series of profits will be shortened to \( n \) periods by some political event.

The minimum price for the firm to remain consistent under such conditions is given by equation (5-17):

\[ p(q) = \frac{[r(1+r)^{n-1}]/[(1+r)^{n-1}-r(1-a)]}{[c(q_0)-c(q)]+c(q)} \]

Note that when there are no political risk (i.e., \( 1-a = 0 \)), equation (5-17) becomes equation (5-14) for \( n = 1 \). Firms facing political risk must command a higher price than firms for which \( 1-a = 0 \) since \( [(1+r)^{n-1}]/[(1+r)^{n-1}-r(1-a)] > 1 \). Grain exporters from countries with controversial foreign policies, or dealing with importing countries contemplating protectionism, are probably more prone to 'milk' their reputations.

The Soviet Union's market, for example, is filled with uncertainty even for U.S. firms trying to build a good reputation. Certain short-run gains may exceed the net

\[ ^7 \text{Instead of a single probability of a shorter series, one can think of a probability distribution of shorter series. The implication remains the same in any case.} \]
present value from a series of profits of uncertain length and this could be a potential explanation for grain quality complaints coming from countries like the Soviet Union and China.

Many U.S. allies have complained about the quality of U.S. grain. Tendencies toward protectionism in these countries (e.g., E.E.C.) and complaining as a means of improving one's bargaining position could perhaps explain a part of this behavior. U.S. agricultural policies may also contribute to the uncertainty of foreign markets. The effect of a grain embargo may not be immediate due to the reputation mechanisms of some countries. First, it might take a long time (i.e., a large $n$ in (5-17)) for the importer to discover that the quality of the wheat imported from the U.S. is not as high as anticipated. Secondly, the reputation mechanism may be such that the U.S. exporter may be able to substitute lower quality wheat more than once before the importer stops buying U.S. wheat. Consequently, the people claiming that the grain embargo imposed by the Carter Administration had no effect could be seriously mistaken. The decline in U.S. wheat exports during the eighties is consistent with this assertion. Past and current political and economic decisions can affect the distribution of the length of the period of time a firm can do business with a foreign customer and this in turn
influence the behavior of the firm in the current and future periods.

Perhaps it can be conjectured that the increase in participation in the export market by additional firms or countries or the attainment of self-sufficiency in these countries has forced some exporters to substitute lower quality wheat in vanishing markets. The Green Revolution may have been a factor in the lowering of wheat quality on the world market.

When price uncertainty is added, it can be shown that a risk loving firm facing risk of a series of profits of shorter length may commend a higher premium to supply wheat of quality $q$ than a risk averse firm facing the same price uncertainty and less risk. It follows that a risk averse firm can drive a risk loving firm out of a market if the latter has to deal with a higher level of risk. This result complements rather than contradicts Sandmo's result since in Sandmo's article, the firms were supposed to face the same level of uncertainty.

**Detection probability and the reputation model**

The main drawback of the results from the previous subsection is the implicit assumption that the importing country is unable to assess the quality of imported wheat. This is not realistic since all importing countries have
inspection services. However, many inspection agencies are understaffed, underfunded, and often corrupt. It can be argued that this characterization applies more to less developed countries, but, according to Ek (1985), F.G.I.S. and the agencies it contracts with should not be excluded.

In this subsection, it will be assumed that the importing country purchasing wheat of quality $q$ has an inadequate inspection service. Given that wheats of quality $q$ and $q_0$ are difficult to visually discriminate from one another, the expected probability of discovering the true quality of look-alike inferior wheat of quality $q_0$ is defined as $1-\alpha$. Consequently, the importing country's probability of receiving wheat of quality $q_0$ from the exporter is $\alpha$. If an exporting firm is discovered substituting wheat of quality $q_0$ for quality $q$, this automatically implies termination of all its selling activities in the high-quality market. No profit can be realized in the low-quality market. When wheat of quality $q_0$, sold as quality $q$, is not intercepted as it enters the importing country, it will take $n$ periods to discover the

\[ \text{\textsuperscript{8}}\text{Different penalties on price may be imposed. It can also be hypothesized that the firm must re-establish its reputation for supplying } q. \text{ If the price received by the firm when it rebuilds its reputation is equal to } c(q_0), \text{ the firm will leave the market, which is a special case of price penalty. Penalties of differing severity change the equilibrium price, but the principle remains the same.} \]
true quality of the shipment. Hence, the exporter can substitute lower quality wheat during n-1 periods with a detection probability of $\alpha$. The reputation can be characterized by

$$R = \alpha q_{t-n}^{+}(1-\alpha)q_{t}.$$  

Profits associated with supplying lower quality wheat $q_0$ are given by

$$E[\pi^D] = E[\alpha((p-c_0)(1+(1/(1+r))^{n-1})).]$$

As before, profits under certainty are

$$E[\pi^H] = E[(p-c)(1+(1/(1+r))^{n}].$$

Using (5-19) and (5-20) and solving for $p$ we obtain

$$E[p] = E[((1+r)^n(c(1-\alpha)+\alpha(c-c_0)-(c-c_0))/(1+r)^n(1-\alpha)+\alpha]$$

which, when $n = 1$, reduces to (5-22).

$$E[p] = E[c+(ar(c-c_0)/(1+r-ar))].$$

The importer will be willing to pay a minimum price $p^*$ for the imported wheat. This price is given by (5-22). Any price below $p^*$ would be considered an attempt to defraud the importer. Other exporting firms facing the same cost and time preference would be alternative suppliers if the exporter charged a price higher than $p^*$. Even though there are positive profits to be made, there will not be entry into the market because the importer has no incentive to change supplier even if offered a lower price.

In a world with technological innovations, the above statement would not apply if the importer were able to
recognize would-be exporters with newer technology from exporters with older technology. The exporter's R&D expenditures would then depend on the ability of the importer to discriminate low-cost from high cost exporters. R&D expenditures would lower the cost of imported wheat but would not necessarily lower the price. Large R&D expenditures can be seen as a barrier to entry which can be translated in market power for the remaining firms in the market. The price given by equation (5-22) would then be a minimum price, not necessarily the equilibrium price. If the exporters incur different unobservable costs to the importer, then the market may cease to exist as low cost exporters may be driven out of the market by high cost exporters that supply wheat of lower quality. If the exporters are allowed to collude, they will fix a price high enough to give high cost exporters the necessary incentive to supply wheat of quality q. The importing country would not benefit from changes in technology.

Equations (5-19) and (5-20) assume that the exporter is risk neutral in the sense that \( U(\pi) = \pi \). It is quite evident that for a risk averse exporter, \( U(E[\pi^D]) < E[\pi^D] \) since \( \alpha \) (the probability of escaping detection by the inspection services of the importing country) no longer carries as much weight. All other things being equal, the '\( \alpha \)' risk averse exporter will need lesser incentive to
behave flawlessly. Under this circumstance, the importer will try to import wheat from risk averse suppliers if they could be identified. Risk averse exporters may force risk neutral exporters to provide wheat of uncertain quality, and, hence, drive them out of the market. If there is also uncertainty concerning future prices, and assuming that the risk averse firms are risk averse with respect to both p and α, the risk neutral firms may drive the risk averse firms out of the market if the risk aversion with respect to p offsets the risk aversion with respect to α.

Reputation and Contamination: A Canadian Example

Over the years, Canada has established itself as an exporter of high quality wheat. Because of the inverse relationship between quality and yield and the size of the market for medium quality wheat, Canada is considering the licensing of new high yielding medium quality varieties known as triple-m (medium hard kernel, medium protein content, medium gluten). According to some studies (Carter, Loyns, and Ahmadi-Esfahari, 1986; Klein, Webber, and Graham, 1986; Veeman, 1987), the introduction of these new varieties could increase aggregate Canadian farm income. While this is debatable, the extent of their recommended planted acreage of medium quality wheat is probably overestimated.
First, reactions from major exporters of medium quality wheat are difficult to predict thus creating a wide range of possible prices for medium quality wheat. In the short-run, if the major exporters were to maximize their market share instead of profits, the production of medium quality wheat in Canada would not be profitable. The profits for Canada from entering the medium quality wheat market cannot be predicted with confidence. Credit, prices (of wheat and other traded goods), and quality are instruments at the disposal of an exporter of medium quality wheat. If used efficiently, they can maintain or increase the exporter's market share. While the size of the pie in the medium quality wheat market may be very tempting, the cost to obtain a small piece may be exorbitant.

Secondly, wheat in Canada is visually inspected, and, because new medium quality wheat varieties are not easily distinguishable from traditional Hard wheat varieties, they can negatively influence Canada's involvement in the high quality market. It is on this point that the discussion below will elaborate.

Using notation from sections 2 and 3, \( q_0 \) denotes lower quality triple-m wheat and \( q \) denotes higher quality Hard Red Spring wheat. Recall that when the minimum price yielding sufficient incentive for an exporter to maintain
its reputation was derived, it was assumed that the exporter had enough low quality wheat to substitute for wheat of higher quality, and that the production of medium and high quality wheat was unknown to the importer. In the analysis presented below, the importer is assumed to be aware of the level of production of medium and high quality wheat that is available to Canada's sole exporter, the Canadian Wheat Board (C.W.B.). The price that a knowledgeable importer is willing to pay should then be a function of the C.W.B.'s ability to substitute low quality, as well as the potential for contamination or error in Canada's grading and inspection services. In this instance, the production of low quality wheat would be detrimental to the price of high quality wheat, since, according to Gilmour (1986), high quality wheat commands premiums for its inherent attributes, consistency, tightness of grade specifications, and low contamination levels (i.e., the mixing of $Q_0$ and $Q$).

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9 It could have been assumed that wheat of quality $q_0$ could be produced instantaneously.

10 It is assumed that C.W.B. does not carry inventories. This is not too unrealistic for Canada; however, in the U.S., large inventories of medium quality wheat enable exporters to substitute lower quality for quality $q$. It follows that knowledgeable importers would not be as willing to pay high prices for high quality wheat. Huge inventories are therefore costly in more ways than one.
The introduction of this new reputation mechanism\textsuperscript{11} is justified by the fact that it is easy for an importer to obtain reasonable information about planted acreages of different varieties of wheat in Canada. Again, it is hypothesized that the importing countries do not have efficient grain inspection agencies. In addition, the exporter does not have the required technology or personnel to perfectly discriminate $Q$ from $Q_0$. It follows that the higher the proportion of $Q_0$ relative to $Q$, the greater the likelihood of a grade misidentification by the exporter.

The goal of the importing countries is to maximize their production function\textsuperscript{12}, $f_j = f(\beta_j Q_0^\mu + \theta_j Q^\tau)$, subject to a budget constraint. The parameter $\beta$ can take positive or negative values depending on the difference in the properties of high and medium quality wheat and on the requirement of the production of the final product. The parameter $\theta$ will in general be greater than or equal to $\beta$ and the same rule applies for $\tau$ and $\mu$.

The budget reflects the exporter contamination problem. The parameters $(1-\delta)$ and $(1-\phi)$ are the

\textsuperscript{11}Such reputation mechanism seems to be used in other industries such as the photocopier industry. Their ads emphasize that a negative externality could be generated by product diversification.

\textsuperscript{12}Maximizing production or profit yields the same solution for the one output case.
probabilities of the share of medium quality wheat in loads of high and medium quality wheat respectively. The budget constraint can be expressed as \( M_j = P[\delta Q + (1-\delta)Q_0] + P_0[\phi Q + (1-\phi)Q_0] \). The maximum expenditure on wheat by importer \( j \) is represented by \( M_j \), while \( P \) and \( P_0 \) are the respective prices of high and medium quality wheats. Maximizing their production subject to their budget constraint, the importers can derive their demand for medium and high quality wheats.

**Two-country example**

For simplicity, it will be assumed that Canada exports wheat to two countries. One of these countries, which will be referred to as the rich country, imports only high quality wheat while the other country, the poor country, does not sufficiently appreciate quality (i.e., \( \beta \approx 0 \) and \( \gamma \approx 0 \)) to purchase the more expensive wheat.\(^{13}\)

Because high and medium wheat serve different purposes, a decline in the price of one should not affect the sales of the other. However, in the presence of

\(^{13}\)The case of the rich country buying medium quality wheat to obtain high quality wheat at a cheaper price is ruled out if a negative \( \beta \) enters the production function and if \( \delta > \phi \). This implies that the production process is negatively affected by the use of wheat not meeting some minimum level of quality (ex. the opportunity cost of segregating the medium from the high quality wheat). This point was brought up to me by Harvey Lapan.
contamination and incomplete information about the quality of the wheat (in the sense that there is a probability \( \alpha \) that the importers will not be able to discriminate wheat of quality \( q \) from wheat of quality \( q_0 \)), the price of medium quality wheat should matter when purchasing (contaminated) high-quality wheat. The degree of substitution between the two types of wheat (which could be close to zero when there is no uncertainty about the quality of wheat) increases with \( \alpha \). The price for the contaminated high-quality wheat can be represented by

\[
(5-23) \quad P^* = W(Q,Q_0;\alpha,T)P(Q)+(1-W(Q,Q_0;\alpha,T))P_0(Q_0).
\]

The weighting variable \( W \) takes the following form,

\[
(5-24) \quad W = [\delta(Q/Q+Q_0,T)f(\alpha)+1],
\]

where \( \delta \) is defined as above and \( T \) is a technology parameter assessing the exporter's ability to deal with the contamination problem. \( P(Q) \) in equation (5-23) refers to the inverse demand for high-quality wheat when the importers can fully discriminate \( Q \) from \( Q_0 \) or when the exporting country does not produce any \( Q_0 \).

The weights reflect the importers' ability to discriminate and the exporter's control over contamination. When the expected importers and exporter's probability of mistakenly grading wheat of quality \( q_0 \) as wheat of quality \( q \) is zero (i.e., \( f(0) = 0 \) and \( \delta = 1 \)), then the price of medium-quality wheat becomes irrelevant.
The function \( f(\alpha) \) reflects the attitude of the individual importer toward the risk of receiving \( q_0 \). Such attitude should depend on the quality differential between \( Q \) and \( Q_0 \) and the production process wheat is used in. Contamination having more serious implications in some processes than in others, the function \( f \) can be expanded to \( f(\alpha;\beta,\theta,\tau,\mu,q,q_0) \). When mixed, the influence of \( Q_0 \) on \( Q \) should also be considered. If the moisture content differential (of \( Q_0 \) and \( Q \)) exceeds a certain level, \( Q \) will deteriorate rapidly, thus lowering the overall quality of the blend. Hence the quality parameters \( q \) and \( q_0 \) can also be thought of proxy variables for the level of risk.

Without much loss of generality, we can express \( f(\alpha) \) in a multiplicative form such as \( f(\alpha) = \phi(\beta,\theta,\tau,\mu,q,q_0)\alpha \). Higher risk aversion and/or higher risk is characterized by a large \( \phi \). When \( f(\alpha) = 0 \), the importer's price will be a simple weighted average of the high and medium quality wheats. The reputation of the firm with probability weights discussed above is equivalent to the case where \( \delta = 1 \). The exponent for \( \delta \) is always greater than or equal to one. Barring a positive externality originating from \( Q_0 \),

\[ \text{Previous studies on the benefits of licensing new varieties of medium quality wheat had implicitly assumed } \delta = 1. \text{ It will be shown that if this assumption does not hold, the benefits from licensing the new varieties could be grossly overestimated.} \]
an exponent smaller than one is incompatible with rationality because it implies that the buyer would 'pay more for less'.

The maximization problem of the exporter is defined by equation (5-25),

\[ \pi = P^*(Q, Q_0; \alpha, T)Q + P_0(Q_0)Q_0 - C(Q, Q_0). \]

The corresponding first order conditions are given by:

\[ \frac{d\pi}{dQ} = P + Q \left( \frac{dP}{dQ} \right) - (1-W) \left( P + Q \frac{dP}{dQ} - P_0 \right) + \frac{dW}{dQ}(P - P_0)Q - \frac{dC}{dQ} = 0, \text{ and,} \]

\[ \frac{d\pi}{dQ_0} = P_0 + Q_0 \left( \frac{dP_0}{dQ_0} \right) + (1-W)Q \left( \frac{dP}{dQ} \right)
+ \frac{dW}{dQ_0}(P - P_0)Q - \frac{dC}{dQ_0} = 0. \]

The first two terms in (5-26) can be regarded as the marginal revenue of Q when there is no uncertainty about the quality of Q. Unless the remaining terms cancel each other, the amount of Q produced and exported under a scenario with incomplete information about quality is likely to differ from the standard case of full information. Note that \( P_0 \) and \( P \) are evaluated at \( Q_0^* \) and \( Q^* \), respectively, since it is the market price of \( Q_0 \) that matters to the importers, not \( P_0(Q) \). Equation (5-27) is also encumbered by terms unique to a quality uncertainty scenario. From the first order conditions, it can be deduced that \( Q_0^* \) will not be identical to \( Q_0 \) obtained in the standard profit maximization problem. As shown by
equation (5-26'), equation (5-26) can be rearranged and perhaps be interpreted more intuitively.

\[ \frac{d\pi}{dQ} = WP + (1-W)P_0 + WQ\left(\frac{dP}{dQ}\right) - dW/dQ(P-P_0) - dC/dQ = 0. \]

From equation (5-23), the first two right hand side components of equation (5-26') are equal to \( P^* \), the price of contaminated high quality wheat. The third and fourth components indicate how \( P^* \) changes as the supply of high quality wheat (Q) increases. The overall change in price is not everywhere negative on the demand curve for contaminated high quality wheat. This peculiarity can be attributed to the positive relationship between Q and W. However, given the concavity of W in Q, the benefits from increasing Q are rapidly negated by the downward sloping demand curve for high quality wheat. It follows that a rational exporter will not operate on the upward sloping portion of the demand for contaminated high quality wheat.

**Contamination and exporter's behavior**

In order to simplify the following comparative statics analysis, some restrictions are imposed:

\[ \frac{d^2P_0}{dQ_0^2} = \frac{d^2P}{dQ^2} = 0. \]

These restrictions imply linear demand curves for Q and \( Q_0 \). Assuming that the exporter operates on the negative portion of the demand for contaminated high quality wheat implies
that the magnitude of the third component of (5-26') exceeds the fourth, \(-\text{WQ}(\text{dP/dQ}) > (P-P_0)\text{QdW/dQ}\).

The above restriction and the concavity of \(W\) imply that

\[(5-28) \, P_0 \geq P+Q(\text{dP/dQ}).\]

Note that when the first weak inequality holds, (5-28) is stronger than the assumption required for a downward sloping demand curve for contaminated high quality wheat. At first glance, this case may seem inconsistent with profit maximizing behavior. One should remember that the marginal revenue from the sale of contaminated high quality wheat (not high quality wheat) should be greater or equal to the price of the medium quality wheat. Equation (5-26) can still hold even when the second term of its third component is negative.

The purpose of the following comparative statics exercise is to assess the impact of the licensing of new varieties of medium quality wheat on optimal export quantities of medium and high-quality wheats. This is basically the problem that the C.W.B. must confront if it allows the licensing of triple-m varieties. The introduction of triple-m wheat will involve a rise in \(a\), a decrease in \(T\) and decreases in \(C(Q_0,Q)\). All the other studies on the subject have focused on the benefits of higher yields (including the argument for a higher price
for high quality wheat would rise from lowering \( Q \), neglecting the contamination and the reputation issues (Carter, Loyns, and Ahmadi-Esfahari, 1986; Veeman, 1987). These issues deserve additional consideration. Because the effects of \( \alpha \) and \( -dT \) reinforce each other and are both felt through their impact on \( W \), (i.e., \( -dQ/dT = (dQ/d\alpha)(dW/dT)/(dW/d\alpha) \)) only a change in \( \alpha \) will be analyzed. The influence of an increase in \( \alpha \) on \( Q_0 \) is determined by (5-29).

(5-29)

\[
\begin{vmatrix}
2(W+QdW/dQ)dP/dQ-d^2C/dQ^2 & (-dW/d\alpha-Qd^2W/dQd\alpha)(P-P_0) \\
(2dW/dQ+Qd^2W/dQ^2)(P-P_0) & -dW/d\alpha(dP/dQ)Q \\
(1-W-QdW/dQ)dP_0/dQ_0 & -dW/d\alpha(dP/dQ_0)-d^2W/dQd\alpha \\
-d^2C/dQdQ_0+dW/dQ_0(QdP/dQ) & (P-P_0)Q \\
(P-P_0)(dW/dQ_0+d^2W/dQdQ_0)
\end{vmatrix}
\]

The expression in the upper left corner of the determinant is negative given the downward sloping demand curve for high quality wheat and the concavity of \( W \) in \( Q \). Given the assumption about the slope of \( P^* \) (or if (5-28) held almost as an equality), the sign of the expression in the lower left corner is clearly negative. Unlike the sign of the expression in the lower right corner, which is unambiguously positive, the sign of the expression in the upper right corner is in general ambiguous. However,
because of the magnitude of the expressions, it can be concluded that the determinant (5-29) is negative.

The decrease in exports of $Q_0$ as $\alpha$ increases is positively related to the magnitude of the price elasticity of $Q_0$. The market for wheat of medium quality being very competitive, underestimating or ignoring the contamination issue could seriously bias the results of a cost/benefit analysis of the licensing of triple-m varieties. This result is very intuitive given the negative impact of the medium-quality market on the high-quality market. This impact is twofold. First, $P^M$ is a weighted average of two prices, one of which is negatively correlated with $Q_0$. A lower $Q_0$ implies a higher $P_0$ which implies a higher $P^M$. Secondly, the effect of $Q_0$ is felt through the weight $W$. Decreasing $Q_0$ will result in an augmentation in $W$.

The effect of $\alpha$ on $Q$ is in general ambiguous despite the fact that an increase in $Q$, holding $Q_0$ constant, inflates $W$. It should be noted that $W$ increases at a decreasing rate with respect to $Q$ while $P$ is assumed to decline at a steady rate. The sign of (5-30) indicates the direction taken by $Q$ following an increase in $\alpha$,
Assuming the term on the right hand side of (5-28) exceeds the left hand side terms, the sign of (5-30) could possibly be negative when W is large (low α, β, Q₀, and large Q) and when dP₀/dQ₀ and dP/dQ are small. Perhaps the intuition behind this result can best be explained graphically. The graph in Figure 5-2 is a simple, but instructive mapping of the first order conditions in Q-Q₀ space. For an equilibrium to be attained, the two first order conditions must hold simultaneously. The equilibrium occurs at the intersection of the two lines QQ and Q₀Q₀. The equilibrium is unique given the convexity of QQ and the concavity of Q₀Q₀. One can see that a corner solution would imply operating on the vertical intercept of the QQ curve. When α increases due to the introduction of triple-m varieties, the two curves shift up. The shift of QQ is accompanied by an increase in its slope. The magnitude of the Q₀Q₀ jump will depend on the slope of the demand for Q₀.

Alternatively, Figure 5-3 illustrates the impact of a change in α on the demand for Q. The most noticeable
FIGURE 5-2. The effect of contamination and imperfect inspection services on optimal production levels of medium and high quality wheats
FIGURE 5-3. The effect of a decrease in the importers' ability to discriminate between medium and high quality wheat on the price of high quality wheat.
characteristic of this graph is the positive slope of $P^*$ at low levels of $Q$. When $Q$ equals zero, $P^M$ is equal to $P_0$ by definition (since $W$ is zero). When $Q$ increases, $W$ increases faster than $P$ decreases thus explaining the positive slope. $W$ increasing at a decreasing rate, its effect inevitably ends up being offset by the negative linear slope of $P$. An increase in $a$ will diminish the positive effect of $W$ and increase the concavity of $P^*$. The higher $\beta$, the more $P^*$ will change. At the same time, an increase in $a$ will also induce a reduction in $Q_0$ which will generate an increase in $P_0$. Again, a large increase in $P_0$ coupled with a change in the effect of $W$ on $P^*$ will yield a higher demand for $Q$. Likewise a small increase in $P_0$ will lower $Q$.

Other effects of licensing

As mentioned before, the introduction of the new triple-m varieties would also influence the exogenous contamination parameter $T$ and the cost of producing wheats. The effect of $T$ is essentially the same as the effect of $a$. The reduction in cost could be inserted in our model by including an exogenous cost parameter ($\Omega$) in the cost function. For example, if costs were specified as $C = C(Q,Q_0/\Omega)$, this would favor the exports of medium quality wheat at the expense of high quality wheat. Results of
partial equilibrium models focusing only on this last point favor the introduction of triple-m varieties.

If Canada were to license the triple-m varieties, it would have the alternative of substituting wheat of lower quality. The price for contaminated high quality wheat \( (P_0^*) \) always exceeding the price for medium quality wheat \( (P_0) \) is not a sufficient condition for a high quality wheat market to exist. If substituting lower quality wheat was more attractive to the exporter than supplying quality \( q \), knowledgeable importers would contract with another supplier or increase their domestic production of wheat. The optimal \( Q \) and \( Q_0 \) determined by solving simultaneously equations (5-26) and (5-27) are the quantities that would be exported when the exporter is supplying wheat of quality \( q \).

The importers who have full knowledge about production levels and cost of production of \( Q \) and \( Q_0 \) would suspect the exporter of cheating if the latter was to alter its production mix. If Canada were the sole exporter of high-quality wheat and there were only two importers, a rich and a poor country, the two alternatives available to the exporter would be

\[
\pi^H = (P_r^* Q^* + P_{0Q_0} - C(Q^*, Q_0))(1+r)/r, \text{ and}
\]

\[
\pi^D = \alpha(P_r^* Q^* + P_{0Q_0} + (1-\alpha)(P_r^* (Q^* - Q_0) + P_{0Q0} + P_p Q_0) - C(Q^*, Q_0) + [(P_{0Q_0} Q_0^h) - C(Q_0^h)/r].
\]
The subscripts \( r \) and \( p \) designate the rich and the poor importers while the subscripts \( *, 0 \) and \( n \) are used to identify the contaminated high quality wheat, the medium quality wheat, and the medium quality wheat after substitution of \( q_0 \). It is evident from these scenarios that the exporter can only sell medium quality wheat to a poor country, after supplying the rich country with wheat of lower quality than \( q \). The optimal \( Q_0 \) is likely to change once it becomes a specialization. For a market for high quality wheat to exist, the price \( P^M \) that solve the equations of the two scenarios must be less than or equal to \( P^* \) defined by (5-23). \( P^M \) can be regarded as a minimum price for the importers to be convinced that the exporter has enough incentive to supply high quality wheat. On the other hand, \( P^* \) is the maximum price that the importers are willing to pay for high quality (contaminated) wheat. It follows that for an equilibrium to exist \( P^M \) must not exceed \( P^* \).

Conclusion

This chapter attempted to rationalize the behavior of U.S. and Canadian wheat exporters. Models of the reputation of the firm were used to achieve this end. At first, it was shown that a competitive market structure may not be optimal for the U.S. wheat export industry. If the
reputation of the firm is country-specific, all the participants will behave like free-riders by marketing lower quality wheat for high quality wheat. Licensing the number of firms or imposing quality standards or quotas are first-best policies. Given the history of the U.S. grain industry, enforcement problems would likely arise if quotas or quality standards were used. The reputation mechanism that accounts for the quality supplied by a firm and the average quality supplied by the country can be used as a potential explanation for the decline in the quality of U.S. wheat at the beginning of the decade. The development of new wheat varieties may have increased the variance of the estimated quality supplied by the firm which would have forced the importers to rely more heavily on the country's reputation to assess wheat quality. As more weight is placed on the reputation of the country, exporters tend to lower wheat quality.

Secondly, risk was shown to influence the behavior of a wheat exporting firm. The probabilities of political or economic events deteriorating the relationships between the importers and the exporters can affect the choice of an exporter's strategy. Uncertainty about future prices and the probability of detection substituting lower quality wheat affect the exporter's attitude in opposite directions.
Contamination problems create uncertainty about quality, and as a result, exert an adverse effect on prices. Regulating the use of the triple-m wheat varieties creating a negative externality on the price of high quality wheat is indeed the first best policy available for the C.W.B., at least until the development of a new variety that can be recognized easily during inspections. From the above analysis, it is impossible to recommend or not recommend the introduction of triple-m varieties by C.W.B. However, it is safe to argue that the validity of the recommendations from previous studies on the topic is questionable.

Additional research on the impact of different market structures should be conducted. Reputation in cartels is a topic that should receive attention in the future. In models where the series of profits are of uncertain length, the probabilities associated with the different lengths could be internalized. The quality level can enter as an argument in the probability distribution of the length of the series of profits. For example, it could be hypothesized that the high quality market is safer, and that the C.W.B.'s risk premium is large enough to delay or even forbid the licensing of triple-m varieties.

Reputation models with different modeling techniques for quality (such as the one in Chapter Six) should be
used. The characteristic approach is appropriate for wheat characteristics like foreign material, dockage and wheat of other classes. It is not as satisfactory for protein content and flour yield.
CHAPTER SIX: RESERVATION QUALITY LEVELS
AND TRADE RESTRICTIONS

As mentioned in Chapter Five, some wheat production processes may demand a minimum quality threshold or a reservation level of quality. Wheat that does not meet the threshold could have a zero, or perhaps negative, marginal product. This is most likely why wheat grading systems in the U.S. and Canada are based on standards for minimum wheat quality characteristics that are thought to be meaningful in the marketplace. Though wheat is a heterogeneous product, blending is common practice among exporters because it can considerably reduce handling and storage costs. However, blending and, probably to a lesser extent, breakage, during the loading and unloading of a vessel causes wheat quality to be a stochastic variable.

When \( \theta \) is the probability that imported wheat will meet a reservation quality \( q_t \), it will vary between zero and one, and can be defined as

\[
(6-1) \quad \theta = \int_{q_t}^{\infty} \left( (2\pi \sigma^2)^{-\frac{1}{2}} e^{-\frac{1}{2} \left( \frac{(q-q_m)^2}{\sigma^2} \right)} \right) dq.
\]

\( ^{1} \)The expected changes in quality during shipment are either omitted or already included in the demand schedule of the importer. If the latter alternative is chosen, \( q_t \) should be interpreted as the reservation quality level considering in transit damages.
The first and second derivatives of (6-1) with respect to mean quality, $q_m$, and the standard error of quality, $\sigma$, depend on the relative location of the quality reservation level, $q^*$, and $q_m$. As Table 6-1 illustrates, when $q^*$ is greater than $q_m$, an increase in the variance of wheat quality can increase the probability that a required minimum quality threshold will be met.

**Blending and Consumer Behavior**

If blending does not create systematic bias in mean wheat quality, then the effect of blending on the standard error of quality is twofold. First, blending will lead to an increase in $\sigma$, and, secondly, it appears that blending can create uncertainty about $\sigma$. Importers are assumed to maximize consumer surplus, defined here as the difference between a function characterizing willingness to pay for imported wheat, and expenditures for imported wheat. Bond (1984) and Bridgeman (1985) have recently exploited the convenience of the 'willingness to pay' function in their studies of gains from intra-industry trade when consumers fail to have identical preferences.

---

2The merits and demerits of consumer surplus as a welfare measure has been debated intensively over the years. For more details about consumer surplus and other welfare measures, the reader is referred to Samuelson (1983), Helms (1985), Willig (1976) and Choi and Johnson (1987).
Table 6-1. Signs of the partial derivatives of $\theta$ at six different locations of $q_t$ on the distribution of quality

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\theta_{qm}$</td>
<td>$+$</td>
<td>$+$</td>
<td>$+$</td>
<td>$+$</td>
<td>$+$</td>
<td>$+$</td>
</tr>
<tr>
<td>$\theta_{q\sigma}$</td>
<td>$-$</td>
<td>$-$</td>
<td>$-$</td>
<td>$+$</td>
<td>$+$</td>
<td>$+$</td>
</tr>
<tr>
<td>$\theta_{qm\sigma}$</td>
<td>$+$</td>
<td>$+$</td>
<td>$-$</td>
<td>$-$</td>
<td>$+$</td>
<td>$+$</td>
</tr>
<tr>
<td>$\theta_{q\sigma\sigma}$</td>
<td>$-$</td>
<td>$+$</td>
<td>$+$</td>
<td>$-$</td>
<td>$-$</td>
<td>$+$</td>
</tr>
<tr>
<td>$\theta_{qmq\sigma}$</td>
<td>$-$</td>
<td>$-$</td>
<td>$-$</td>
<td>$-$</td>
<td>$+$</td>
<td>$+$</td>
</tr>
</tbody>
</table>

Though the current analysis is restricted by a partial equilibrium framework, the implications of the results are far reaching. The importer's maximization problem can be illustrated as

(6-2) $\text{Max. } W(\theta(qm,\sigma;q_t)Q) - P(qm)Q$. 
The volume of imported wheat with mean quality \( q_m \) is represented by \( Q \). Since the variance of quality is not a factor in the U.S. or Canadian wheat grading process, it is not an argument in the price of wheat, \( P \). Only the grade (i.e., mean quality) is important in determining wheat prices. This is compatible with the small country assumption which demands that an importer's terms of trade be exogenous. The importing country cannot improve its terms of trade by reducing its volume of imports, nor can it force an exporter to discount its wheat based on characteristics (such as \( a \)) that are not already in the grading system (\( q_m \)). The assumption that an importer's terms of trade must be exogenous will be relaxed in a subsequent section of this Chapter.

First order conditions with respect to \( Q \) and \( q_m \) are given below.

\[(6-3) \quad W' \theta - P = 0.\]

\[(6-4) \quad W' \theta q_m Q - P q_m Q = 0.\]

\( W' \) is the first partial derivative of \( W \) with respect to the probability that the imported wheat will be 'usable'. \( \theta q_m \) represents the first partial derivative of \( \theta \) with respect to mean quality. In the above equations, marginal utility from increasing \( Q \) or \( q_m \) equals the marginal cost of \( Q \) or \( q_m \).
The second order conditions can be verified by imposing restrictions which guarantee that the determinant of the corresponding Hessian matrix will be positive. Imposing \(-\theta_{qmqm} + P_{qmqm} > 0\) was found to be sufficient for a maximum solution to exist. As noted earlier, the first effect of blending is felt through the standard error of quality, \(\sigma\). This effect can be analyzed using Cramer's rule and the positive sign of the determinant of the Hessian matrix.

\[ (6-5) \quad \frac{dQ}{d\sigma} = (W'\theta Q + W')(P_{qmqm}\theta_\sigma - W'\theta_{qmqm}\theta_\sigma Q) \]
\[ + W'W\theta_{qm}(\theta\theta_{qmqm} - \theta_{qmqm}\theta_\sigma). \]

\[ (6-6) \quad \frac{dq}{d\sigma} = (W'W\theta Q)(\theta_{qmqm}\theta_\sigma - \theta_{qmqm}\theta_\sigma). \]

As expected, the signs of \(\frac{dQ}{d\sigma}\) and \(\frac{dq}{d\sigma}\) are somewhat ambiguous. Depending on the location of \(q_t\) vis-a-vis \(q_m\), this ambiguity can be resolved. The comparative statics results obtained by using locations one (1) through six (6) at the top of Table 6-1 are summarized in Table 6-2.

The uncertainty effect can be analyzed by taking the expectations of the first order conditions, (6-3) and (6-4), and solving simultaneously. The presence of uncertainty about \(\sigma\) makes \(\theta\) a random variable. The first order conditions can be expanded as

\[ (6-7) \quad E[W']E[\theta] + \text{cov}(W', \theta) - P = 0, \quad \text{and} \]
\[ (6-8) \quad E[W']E[\theta_{qm}Q] + \text{cov}(W', \theta_{qm}Q) - P_{qm}Q = 0. \]
Table 6-2. Effects of an increase in $\sigma$ on $q_m$ and $Q$

<table>
<thead>
<tr>
<th>Location</th>
<th>Sign of $dQ/d\sigma$</th>
<th>Sign of $dq_m/d\sigma$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>2</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>3</td>
<td>$\pm$</td>
<td>$\pm$</td>
</tr>
<tr>
<td>4</td>
<td>+</td>
<td>$-$</td>
</tr>
<tr>
<td>5</td>
<td>$\pm$</td>
<td>$-$</td>
</tr>
<tr>
<td>6</td>
<td>$\pm$</td>
<td>$-$</td>
</tr>
</tbody>
</table>

The relative magnitudes of the optimal $q_m$ and $Q$ under uncertainty versus certainty are ambiguous and depend on the location of the reservation quality level. Given that the function $W$ is concave, the covariance term in (6-7) will be negative, except when evaluated at $q^*_n = q_m$ where it will be zero. Consequently, it can be deduced that $E[W']E[\theta]$ is greater than $E[W'\theta] = P$.

The sign of the covariance term in (6-8) will also change, depending on the location of $q^*_n$ in the distribution of imported wheat quality. The covariance term is positive at locations 1, 2, and 4, and is negative elsewhere. All the terms in (6-7) and (6-8), except the covariance terms, can be differentiated. The resulting equations are given below.

$$(6-9) \, W''\theta^2 dQ + (W''\theta q_m \theta Q + W'\theta q_m - P q) dq_m.$$
Given the signs of the covariances in (6-7) and (6-8), Table 6-3 indicates that the above equations should take different signs at varying \( q_t \) locations. Changes in \( Q \) and \( q \) must simultaneously satisfy the signs for equations (6-9) and (6-10) noted in Table 6-3. The last two columns indicate the resulting changes in \( Q \) and \( q \).

The changes in \( Q \) and \( q \) attributable to uncertainty appear to be ambiguous more often than not. Though it is not possible to arrive at a unique solution for the effect of uncertainty on \( Q \) and \( q_m \), additional information can be extracted from Table 6-3 and equations (6-9) and (6-10).

Table 6-3. Sign of (6-9) and (6-10) at different \( q_t \)'s and corresponding possible changes in \( Q \) and \( q_m \)

<table>
<thead>
<tr>
<th>Location</th>
<th>Sign of (6-9)</th>
<th>Sign of (6-10)</th>
<th>Change in ( Q )</th>
<th>Change in ( q_m )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>2</td>
<td>+</td>
<td>-</td>
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<td>+</td>
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<tr>
<td>3</td>
<td>+</td>
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<tr>
<td>4</td>
<td>+</td>
<td>-</td>
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<tr>
<td>5</td>
<td>+</td>
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<td>±</td>
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<tr>
<td>6</td>
<td>+</td>
<td>+</td>
<td>±</td>
<td>±</td>
</tr>
</tbody>
</table>
Setting (6-9) and (6-10) to zero, graphs of the first order conditions under certainty in Q-qm space can be drawn. The solution to the maximization problem under certainty is depicted by the intersection of the two dQ/dqm curves associated with (6-9) and (6-10). The signs of (6-9) and (6-10) in Table 6-3 are used to define the feasible sets of solutions. The sets of feasible solutions for the six locations of qt are illustrated in Figure 6-1. Mean quality increases and variance decreases at locations 1, 2, and 4. When qm-σ < qt < qm (location 3) and when qt > qm+σ (locations 5 and 6), an increase in Q implies a decrease in qm and vice versa. It is also possible for both Q and qm to decrease. The change in the sign of θqmqm when qt is positioned to the right side of qm gives rise to an ambiguity concerning the relative steepness of the slopes of (6-9) and (6-10). If the slopes were identical everywhere, a solution would not exist for location 4. Ruling out this possibility, when either Q or q moves in one direction, the change in the other variable must be in the opposite direction.

It could be argued that in reality, the parameter qt is more likely to be located to the right of qm. On this premise, importers would import a lower volume of upgraded wheat. This behavior is reflected in Table 6-4. The volume of Hard wheat (higher quality) exported by the U.S.
FIGURE 6-1. Possible solution sets for $Q$ and $q_m$ at six different $q_t$ locations when $\sigma$ is uncertain.
Table 6-4. U.S. wheat exports by class (million bushels)\(^a\)

<table>
<thead>
<tr>
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<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Hard Red Winter</td>
<td>754</td>
<td>679</td>
<td>704</td>
<td>717</td>
<td>525</td>
<td>555</td>
<td>636</td>
</tr>
<tr>
<td>Hard Red Spring</td>
<td>205</td>
<td>239</td>
<td>221</td>
<td>183</td>
<td>154</td>
<td>169</td>
<td>231</td>
</tr>
<tr>
<td>Soft Red Winter</td>
<td>460</td>
<td>325</td>
<td>222</td>
<td>253</td>
<td>162</td>
<td>129</td>
<td>151</td>
</tr>
<tr>
<td>White</td>
<td>270</td>
<td>207</td>
<td>220</td>
<td>210</td>
<td>162</td>
<td>151</td>
<td>151</td>
</tr>
<tr>
<td>Durum</td>
<td>82</td>
<td>59</td>
<td>62</td>
<td>61</td>
<td>51</td>
<td>70</td>
<td>59</td>
</tr>
</tbody>
</table>

\(^a\)United States Department of Agriculture, 1985-87; United States Wheat Associates, 1985-87 (projections).

has remained fairly constant during the 1981-87 interval while a downward trend has characterized the movements of U.S. exports of Soft wheats (such as White and Soft Red Winter wheats). U.S total exports have decreased while the composition of these exports have shifted toward higher quality classes of wheat.

Behavior of Exporters and Trade Restrictions

The objective of the next model is to investigate the behavior of an exporter in a regulated environment (quality standards (\(q_m\) fixed), quotas, and specific and ad-valorem tariffs). As before, a comparison of the magnitude of choice variables under certainty and uncertainty (when \(P\) is a random variable) is also discussed. Perhaps the origin of (or solution to) quality problems can be linked to
protectionism or to the uncertain nature of the environment wheat exporters operate in. The importers' strategy of not granting a long-term agreement to the exporter until the latter has proven itself may be inefficient. Long-term contracts could make the benefits of ethical conduct more appealing by stabilizing the exporter's returns.

The impact of trade restrictions has been analyzed recently by Das and Donnenfeld (1987); however, the framework used here differs from theirs in two ways. First, quality is not defined only by its mean, but also by its variance. Secondly, the importers are assumed to have reservation quality levels, which is more compatible with feeding and bread-making purposes.

In a free-trade environment, the exporter has control over the quantity $Q$, the mean quality $q_m$, and blending proxied by $\sigma$. The parameter $q_t$ depends on the importers preferences, and is therefore exogenous. The model can be represented as follows:

\[ (6-11) \text{Max. } P(\sigma; q_t)Q - C(q_m, \sigma, Q) - Q^2. \]

The parameter $\sigma$ enters the price function on the grounds that the importers incur cleaning costs or losses in production positively related to the variance of the quality of wheat. The size of the partial derivative $P_\sigma$ clearly depends on the importer's market power and ability to bargain. $P$ should be interpreted as the price of a unit
of wheat meeting the reservation quality level \( q^* \). The introduction of \( \theta \) in the revenue function reflects the importers unwillingness to pay for foreign material and wheat of inferior quality. The exporter's market power issue was sidelined to ease the derivations and also because at this stage, U.S. wheat exporters are perhaps behaving more like perfect competitors than oligopolists. This assumption should not damage too extensively the generality of the conclusions derived below.

Transportation costs \( T \) increase in a quadratic fashion as \( Q \) increases. In a free-trade situation, the first order conditions with respect to \( Q, q, \) and \( \sigma \) could be derived and expressed as

\[
(6-12) \quad P - C_Q - 2TQ = 0, \\
(6-13) \quad P \theta_{qm} Q - C_{qm} = 0, \text{ and} \\
(6-14) \quad P \theta_{gq} Q + P \theta_{qg} Q - C_g = 0. 
\]

The quota

The first situation analyzed is one in which a wheat importing country imposes a quota on the volume of wheat imported from the U.S. The motive for trade restrictions is not rationalized. Political or economic arguments could be advanced but whether the importing country makes an efficient decision is irrelevant for the purpose of this
exercise. A binding quota invalidates equation (6-12) since $Q$ is decided by the importer. The relevant first order conditions (6-13) and (6-14) can be differentiated to verify the second order conditions and for comparative static purposes. Again the derivations are complicated by the fact that the partial derivatives of $\theta$ take different signs depending on the location of $q_t$ relative to $q_m$. The effect of a quota on the mean quality $q_m$ can be assessed by computing $-dq_m/dQ$ as in (6-15).

\[
\left(6-15\right)\quad -(|A|)^{-1} \begin{vmatrix} -P_{q_m} + C_{q_m} & P_{q_m} Q + P_{q_m} Q - C_{q_m} \\ P_{q_m} - P_{q_m} + C_{q_m} & P_{q_m} Q + 2P_{q_m} Q + P_{q_m} Q - C_{q_m} \end{vmatrix}.
\]

$|A|$ is the determinant of the Hessian matrix and must be positive. Note that from (6-13), $P_{q_m} = C_q/Q$ and from the convexity of the cost function, $C_q/Q < C_{q_m} Q$ making the expression in the upper left corner unambiguously positive. The expression $-P_{q_m} - P_{q_m} + C_{q_m}$ could be simplified to $-C_q/Q + C_{q_m} < 0$ from (6-14). It can be shown that for the second order conditions to hold, the expression in the bottom right must be negative. This holds for the six locations of $q_t$. The impact of a quota on mean quality is clearly positive when $P_{q_m} Q + P_{q_m} Q - C_{q_m}$ is negative (or close to

\[3\]Beghin (1987) using a game theoretic framework has demonstrated that countries do not make efficient decisions even when political motives are taken into considerations.
zero) and ambiguous otherwise. If the cost function was written as \( C = f(Q) + \sigma(q_m, \sigma) \) and if \( P_\theta q_m Q + P_\sigma q_m Q - C q_m < 0 \), the quota would induce the exporter to lower mean quality. One would expect \( P_\theta q_m Q + P_\sigma q_m Q - C q_m \) to be negative when the price of wheat meeting the reservation quality level is heavily discounted in response to a high degree of variance or when \( \theta q_m \) assumes a negative sign (locations 3 and 4). The positive effect of a quota on the quality of wheat supplied is supported by the work of Falvey (1979), Rodriguez (1979), and Das and Donnenfeld (1987).

The innovative part of the above model lies in the use of an additional variable defining quality and in the use of \( \theta \) in the revenue function. Therefore, one cannot conclude that a quota induces a rise in quality without considering the effect on \( \sigma \). It is conceivable that for some processes, the variance of quality is more important quality parameter than mean quality. The change in \( \sigma \) following the imposition of a quota is determined by (6-16).

\[
(6-16) \quad -(|A|)^{-1} \begin{vmatrix} P_\theta q_m Q - C q_m & -P_\theta q_m + C q_m Q \\ P_\sigma q_m Q + P_\theta q_m Q - C q_m & -P_\sigma - P_\theta + C Q \end{vmatrix}.
\]

As for (6-15), the multiplier in front of the determinant is negative. The expression in the upper left corner is negative when \( q_t < q_m \) and is assumed to be negative for \( q_t \).
The first two terms in the bottom right expression are equal to \(-C_g/Q\) which is assumed to be smaller than \(-C_{Qg}\). The expressions in the upper right and lower left corners have been investigated above and based on this information, it can be concluded that a quota will encourage the exporter to blend less when \(P\sigma_q\theta_{qm}Q + P_q\theta_{qm} < C_{qm}\) < 0. This result is reversed if \(C_{qm}=0\) and \(C_{QQ}=0\).

The effect of a quota on the choice of \(\sigma\) could be positive if the effect of \(\sigma\) on the marginal cost of improving the mean quality is large and positive \((P\theta_{qm}Q + P\sigma_q\theta_{qm}Q - C_{qm} > 0)\). The positiveness of this latter expression is reinforced when \(\theta_{qm}\) is positive as in location 1.

The wheat quality mean and variance can either increase or decrease after the imposition of a quota, depending on the importer's ability to negotiate a discount or a compensation that covers cleaning costs associated with a greater variance, as well as on the exporter's cost function. The ability for less developed countries (L.D.C.'s) to measure the mean let alone the variance of wheat quality is very limited. In addition, the dependency of some L.D.C.'s on U.S. aid probably restricts their bargaining power. It follows that, in the presence of market imperfections, a quota would not necessarily force the exporter to improve wheat quality as predicted by previous studies.
The minimum (mean) quality standard

A popular and more subtle trade barrier is the minimum quality standard. Many agricultural products are subject to minimum quality standards. The political appeal of this particular type of trade barrier is the hidden implicit level of protection it generates to shelter domestic producers from foreign competition. The protection level associated with minimum quality standards cannot be measured readily by looking at a percentage or a nominal monetary rate as for ad-valorem and specific tariffs. It can also be argued by proponents of minimum quality standards that the latter are primarily aimed at protecting consumers. However, one should remember that consumers need protection only in the presence of a market failure (i.e., when quality is not observable ex-ante). In the absence of market failure, regulating quality constraints the consumers utility maximization problem and is not optimal by virtue of Le Chatelier's principle.

The effects of a minimum quality standard on Q and σ can be determined by differentiating equations (6-12) and (6-14). The comparative static analysis (dQ/dq, dσ/dq) is displayed in (6-17) and (6-18). Note that for the second order conditions to be respected, the following must hold: \( P_0\sigma^2Q+2P_0\sigma Q+P_0\sigma -C_\sigma < 0 \). In addition, if \( C_\sigma/Q-C_Q\sigma \) is
positive, it must also be 'small'. The latter is a necessary condition.

\[
(6-17) \quad (|A|)^{-1} \begin{vmatrix} -C_{qm}/Q + C_{qmQ} & C_{o}/Q - C_{Qo} \\ -P_o \theta_{qm} Q + P_{qmo} Q + C_{qmo} & P_{o} \theta_Q + 2P_o \theta_o Q + P_{o} \theta_o - C_{o} \end{vmatrix}.
\]

\[
(6-18) \quad (|A|)^{-1} \begin{vmatrix} -C_{QQ} - 2\tau & -C_{qm}/Q + C_{qmQ} \\ C_{o}/Q - C_{Qo} & -P_o \theta_{qm} Q - P_{qmo} Q + C_{qmo} \end{vmatrix}.
\]

The cost function being convex in Q and q, and in light of the restrictions imposed for the second order conditions to hold, it can be concluded that a minimum quality standard will force a decrease in the volume of exported wheat if \( P_o \theta_{qm} Q + P_{qmo} Q - C_{qmo} < 0 \). (If the marginal costs of increasing quality and lowering the variance are independent of Q, then Q will increase.) The effect is ambiguous when \( P_o \theta_{qm} Q + P_{qmo} Q - C_{qmo} > 0 \). From (6-18), the change in the variance of the quality of exported wheat is negative when \( P_o \theta_{qm} Q + P_{qmo} Q - C_{qmo} < 0 \). However, when \( P_o \theta_{qm} Q + P_{qmo} Q - C_{qmo} > 0 \) which probably holds at \( q_e < q_m - (2\sigma^2) \), the likelihood of a diminution in \( \sigma \) is smaller. The same argument applies if the cost function's convexity in Q is very pronounced.\(^4\) Because the variance of quality does not necessarily decrease, it cannot be concluded that importers

\[^4\text{If the cost function was a Cobb-Douglas function, the exponent for Q would be large.}\]
would be better off in terms of quality after the imposition of a minimum quality standard.

The specific tariff

The analysis of the specific tariff can be carried out by rewriting the revenue function of equation (6-11) as follows:

\[(6-19) \quad (P(\sigma)e^{-T})Q.\]

This particular formulation implies that the importer has to pay a tariff on the unwanted wheat.\(^5\) Adding transportation costs to the tariff, the importer ends up paying dearly for dockage and foreign material. Equation (6-12) is slightly modified and becomes (6-12').

\[(6-12') \quad Pe^{-T} - C_Q - 2TQ = 0.\]

By totally differentiating (6-12'), (6-13), and (6-14), the exporter's response to the imposition of a specific tariff on its wheat can be determined. As opposed to the previous cases, the sign of \(|A|\) for the analysis of tariffs is negative. The restrictions imposed in the previous cases \((P_{\theta \theta}Q + P_{\sigma \theta}Q - C_{\theta \theta} > 0; \quad P_{\sigma \sigma}Q + 2P_{\sigma \theta}Q + P_{\sigma \sigma} - C_{\sigma \sigma} < 0; \quad \text{and} \quad C_{\sigma}Q < C_{\sigma}Q > 0)\) were used again. As expected, a specific tariff on exports will decrease the demand for exports. The apparent ambiguity is resolved when one glances at the

\(^5\)The tariff assessment is calculated on a straight tonnage basis as in the Economic European Community. The importing country's revenue is TQ not T0Q.
second order conditions. The effect of a specific tariff is represented by (6-20).

\[
\begin{vmatrix}
1 & C_{qm}/Q-C_{qgm} & C_{q}/Q-C_{q}
0 & P\theta_{qgm}Q-C_{qgm} & P\theta_{qmo}Q+P\theta_{qgm}Q-C_{qmo}
0 & P\theta_{qmq}Q+P\theta_{qgm}Q-C_{qmo} & P\theta_{qg}Q+2P\theta_{qg}Q+P\theta_{qg}C_{qg}
\end{vmatrix}
\]

From (6-21), it is evident that the specific tariff should also force the exporter to upgrade the mean quality of its wheat if $P\theta_{qmo}Q+P\theta_{qgm}Q-C_{qmo} < 0$. If the marginal costs of increasing $q_m$ and lowering $\sigma$ were independent of $Q$, $q_m$ would decrease. When this inequality is reversed, the change in $Q$ following the imposition of a specific tariff becomes ambiguous.

\[
\begin{vmatrix}
-C_{Qq}^{-2}\tau & 1 & C_{q}/Q-C_{q}
C_{qm}/Q-C_{qgm} & 0 & P\theta_{qmo}Q+P\theta_{qgm}Q-C_{qmo}
C_{q}/Q-C_{qg} & 0 & P\theta_{qg}Q+2P\theta_{qg}Q+P\theta_{qg}C_{qg}
\end{vmatrix}
\]

Assuming $P\theta_{qmo}Q+P\theta_{qgm}Q-C_{qmo} < 0$, the determinant below shows\(^3\) that the exporter's response to a specific tariff is likely to include a decrease in the variance of the quality of its wheat. This strategy improves revenues by increasing $P\theta$ more than it increases costs. Variance increases if $C_{Qq}, C_{Qqm} = 0$. When $P\theta_{qmo}Q+P\theta_{qgm}Q-C_{qmo} > 0$, profit maximization may induce the exporter to increase $\sigma$. The exporter's reaction for $\sigma$ is given by (6-22).
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\[
\begin{vmatrix}
-C_{QQ}^2 & C_{qm}/Q-C_{Qm} & 1 \\
\frac{C_{qm}}{Q-C_{Qm}} & P_{qmqm}Q-C_{qmQ} & 0 \\
\frac{C_{q}}{Q-C_{Qq}} & P_{qmQ}Q+P_{m}Q-C_{qmQ} & 0 \\
\end{vmatrix}
\]

It is easy to see that transportation costs have the same effects as a specific tariff. The difference between a specific tariff and an increase in transportation costs lies in the relative magnitude of their effects. The column vector \((1, 0, 0)'\) used in the comparative static analysis of a specific tariff is replaced by \((2Q, 0, 0)'\) when the impact of transportation costs are under investigation.

The ad-valorem tariff

The investigation of the effects of an ad-valorem tariff on an exporter's choice variables requires a modification of the revenue function in (6-11).

\[
(6-11') P\theta Q(1-t)
\]

This modification of the revenue function alters the first order conditions to the wheat exporter's maximization problem given by (6-12)-(6-14). The new equations for the first order conditions are given below.

\[
(6-12''') P\theta(1-t)-C_{Q}-2\tau Q = 0.
\]
\[
(6-13''') P_{qm}Q(1-t)-C_{qm} = 0.
\]
\[
(6-14''') P_{q}Q(1-t)+P_{m}Q(1-t)-C_{q} = 0.
\]
The impacts of an ad-valorem tariff on the volume, mean quality and variance of the quality of exported wheat are all ambiguous as shown by (6-23) through (6-25). This clearly differs from the effects of a specific tariff or quota and from previous literature. The dissimilarities of specific and ad-valorem tariffs have been stressed by Falvey (1979) in a context similar to the one above and by Lloyd and Falvey (1986) in a study on protectionism under price uncertainty. The sources of ambiguity in result come from the interactions in the cost function and in the interactions in $\theta$, especially when one considers all six possible locations for $q^*$, the reservation quality level. The results become determinate if the volume $Q$ is assumed to be independent from mean quality $q_m$ and variance $\sigma$ in the cost function. For example, the cost function could be specified as follows: $f(Q)C(q_m,\sigma)$. If this was the case, output would as usual fall when the tariff increases while mean quality and variance would decrease and increase respectively. Ad-valorem tariffs should not be used by importing countries as an attempt to raise quality and

---

6Falvey argued that, in a world in which goods of different quality are traded, a specific tariff lower the relative price of higher quality varieties consequently alters the composition of imports. Relative prices remain the same after the imposition of an ad-valorem tariff and so does the composition of imports.
protectionist measures of this kind may have contributed to the "quality problem" in the world market.

\[
(6-23) \quad |A|^{-1} \begin{vmatrix} \frac{(C_0+2\sigma Q)}{(1-t)} & C_{qm}/Q-C_{qm}Q & C_\sigma/Q-C_{Q\sigma} \\ -C_{qm}/1-t & P_\sigma Q_{qm}Q(1-t) & (P_\sigma Q_{qm}Q+P_\sigma Q_{q Q\sigma})Q(1-t) \\ C_\sigma/1-t & (P_\sigma Q_{qm}Q+P_\sigma Q_{q Q\sigma}) & (P_\sigma Q_{qm}Q+2P_\sigma Q_{q Q\sigma}+P_\sigma Q_{q Q\sigma})Q(1-t) \end{vmatrix}
\]

\[
(6-24) \quad |A|^{-1} \begin{vmatrix} -C_{Q}Q^{-2t} & \frac{C_0+2\sigma Q}{(1-t)} & C_\sigma/Q-C_{Q\sigma} \\ C_{qm}/Q-C_{qm}Q & C_{qm}/1-t & (C_{qm}Q+P_{\sigma Q_{qm}Q}(1-t)-C_{qmQ}) \\ C_\sigma/Q-C_{Q\sigma} & C_\sigma/1-t & (P_{\sigma Q_{qm}Q}+2P_{\sigma Q_{q Q\sigma}}+P_{\sigma Q_{q Q\sigma}})(1-t)-C_{Q\sigma} \end{vmatrix}
\]

\[
(6-25) \quad |A|^{-1} \begin{vmatrix} -C_{Q}Q^{-2t} & C_{qm}/Q-C_{Qqm} & C_0+2\sigma Q \\ C_{qm}/Q-C_{Qqm} & P_{\sigma Q_{qm}Q}(1-t)-C_{qmQ} & C_{qm}/1-t \\ C_\sigma/Q-C_{Q\sigma} & (P_\sigma Q_{qm}Q+P_\sigma Q_{q Q\sigma})(1-t)-C_{qmQ} & C_\sigma/1-t \end{vmatrix}
\]

**Price uncertainty and quality choices**

Hypothesizing that price uncertainty may be at the origin of the quality problem in the U.S. wheat export industry, this subsection will attempt to compare the wheat exporter's behaviors under price uncertainty and certainty. The source of the uncertainty stems from the uncertainty about the importers bargaining tactics and the way complaints are handled. For example, the importers may complain after every purchase hoping to get a discount even when the quality of the wheat purchased meets quality...
expectations. Alternatively, price uncertainty can originate from the adoption of a system for which quality is determined at the point of import. The uncertainty is totally exogenous to the model. An expected utility framework is used to facilitate the analysis of the exporter's response under uncertainty. It is assumed that the exporters goal is to maximize the expected utility derived from profits. Their expected utility is represented by (6-26).

\[ E[U(P(\sigma)Q-C(qm,\sigma,Q)-\tau Q^2)]. \]

Assuming the second order conditions are met, an optimal solution is reached when equations (6-27) through (6-29) simultaneously hold.

\[
\begin{align*}
(6-27) & \quad E[U'(P-C_Q-2\tau Q)] = 0. \\
(6-28) & \quad E[U(P_{qm}Q-C_{qm})] = 0. \\
(6-29) & \quad E[U(P_0Q+\theta_0Q-C_{Q})] = 0.
\end{align*}
\]

\( P \) being a random variable, the above first order conditions can be written as follows:

\[
\begin{align*}
(6-27') & \quad E[U'] E[P-C_Q-2\tau Q] + \text{cov}(U', P-C_Q-2\tau Q) = 0 \\
(6-28') & \quad E[U'] E[P_{qm}Q-C_{qm}] + \text{cov}(U', P_{qm}Q-C_{qm}) = 0 \\
(6-29') & \quad E[U'] E[P_0Q+\theta_0Q-C_{Q}'] + \text{cov}(U', P_0Q+\theta_0Q-C_{Q}) = 0
\end{align*}
\]

For \( U'' < 0 \), the covariance term in (6-27') will always be negative regardless of the location of the reservation level \( q_t \) on the distribution of quality. Differentiating \([P-C_Q-2\tau Q]\) in (6-27') and forcing the resulting equation
(6-30) to be positive, it becomes obvious that if \( q_m \) and \( \sigma \) remain at their 'certainty' level, \( Q \) must decrease.

\[
(6-30) \ (P_{\theta q_m} - C_{Q q_m}) dq_m + (P_{\sigma q_m} + P_{\theta q_m} - C_{Q q_m}) d\sigma + (-C_{Q Q} - 2\tau) dQ > 0
\]

The covariance term in (6-28') is always negative since \( \theta_{q_m} \) is positive everywhere as indicated in Table 6-1.

Differentiating the terms inside the second expectation component of (6-28'), the following must hold:

\[
(6-31) \ (P_{\theta q_m q_m} Q - C_{q_m q_m}) dq_m + (P_{\theta q_m q_m} Q + P_{\theta q_m q_m} Q - C_{q_m q_m}) d\sigma + \]

\[
(P_{\theta q_m} - C_{Q q_m}) dQ > 0.
\]

The above \( dq_m \) multiplier is assumed to be negative despite the change in the sign of \( \theta_{q_m q_m} \) when \( q_t > q_m \). This implies that when \( \sigma \) and \( Q \) are fixed at their 'certainty' level, \( q_m \) must decrease. The covariance term in (6-29') is clearly positive when \( q_t < q_m \), and ambiguous when \( q_t > q_m \). The differentiation of \( [P_{\theta Q} + P_{\theta Q} Q - C_{Q}] \) in (6-29') yields (6-32).

\[
(6-32) \ (P_{\theta q_m q_m} Q + P_{\theta q_m q_m} Q - C_{q_m q_m}) dq_m + (P_{\theta q_m q_m} Q + 2P_{\theta q_m q_m} Q + P_{\theta q_m q_m} Q - C_{q_m q_m}) d\sigma +
\]

\[
(P_{\theta Q} + P_{\theta Q} - C_{Q Q}) dQ = < 0.
\]

The multipliers for \( dq_m \) in (6-30), \( d\sigma \) and \( dQ \) in (6-31) and \( dq_m \) and \( d\sigma \) have ambiguous signs under uncertainty. Unless additional assumptions are made, it is impossible to determine the changes in \( Q, \ q_m \), and \( \sigma \) that can be attributed to uncertainty. Assuming that all the multipliers are negative, it can be conjectured that price uncertainty would cause a decrease in \( Q \) and an augmentation in \( q_m \) and \( \sigma \). If the model was simplified to account only
for $Q$ and $q_m$ (i.e. $\text{Max. } E[U(P(q_m+\delta)Q-C(q_m,Q))]$), it would not be difficult to show that uncertainty about $\delta$, a random variable with mean of zero, would change the exporter's behavior who would then sell a smaller volume of higher quality wheat. Under price uncertainty, the increase in average quality can be seen as a way for the exporter to protect themselves against the occurrence of very low prices. The smaller volume under price uncertainty can also be seen as a deliberate attempt to minimize substantial losses in situations when prices below the mean are realized.

Conclusion and Application

In order to capture the demands of some production processes on input quality, a reservation quality parameter, $q_t$, was introduced in this chapter. The importers preferences are such that wheat not meeting the reservation quality level yield minute or even negative marginal utility. This assumption is used because some wheat characteristics cannot be substituted for by a larger quantity. Protein is a good example of such a characteristic.

The importers response to exogenous changes in the variance of the quality of imported wheat could be characterized by a lower demand of higher quality wheat.
when the reservation quality level or threshold is below the quality level, $q_m$. The consequences of an uncertain variance depends on the location of $q_c$. However, the most probable scenario suggests that uncertainty will induce the importers to buy a smaller volume of higher quality wheat.

An attempt was made to determine the exporter's behavior when the importers impose trade barriers. As expected different trade barriers generate different outcomes which are influenced by the importers' ability to negotiate a discount for higher variance and on the effectiveness of blending in reducing the exporter's cost. In the context of a reservation quality level, quality has to be defined by the mean and the variance. An increase in the mean quality will not appease the complainant importers if the variance also increases substantially. The effects of price uncertainty on the exporter's choice variable were in general ambiguous. However, in a special case, the volume and the variance were found to decrease and the mean to increase.

Uncertainty about future prices and certainty about the length of the 'horizon' should give more incentives to the wheat exporters to improve quality. The institutional implication is for the price to be determined at the destination point instead of at the export point, and for the importers to offer long-term agreements. Perhaps such
long-term agreements can best be negotiated between countries since they are likely to involve other goods as well. This is supported by the fact that Canada has a higher proportion of long-term agreement than the U.S. (Carter, 1983). Once again, a single government regulated agency may be optimal.
CHAPTER SEVEN: CONCLUSIONS AND FUTURE RESEARCH

This study analyzed the implications of heterogeneous quality in the international wheat market and attempted to explain the decline in U.S. wheat exports between 1980 and 1986. Theoretical models were used to determine the effects of heterogeneous quality on the behavior of importers and exporters. Two approaches were used to model quality. The characteristic approach developed by Lancaster (1966) was used in Chapters Three, Four, and Five. Chapter Six was based on the assumption that importers have a reservation quality level or threshold. While the former approach was adequate to investigate the effects of changes in characteristics such as the percentage of foreign material or dockage, the latter approach better suited the specific nature of characteristics such as protein content.

The impact of an observable improvement in the quality of imported wheat depended on the latter's price elasticity. The volume of imports increased when the price elasticity exceeded one and vice versa. An indirect utility function was derived to analyze the welfare effect of observable quality changes. Using an extension of Roy's identity, the Marshallian demand for imported wheat was also derived. Quality uncertainty was shown to increase
the level of self-sufficiency in the production of domestic wheat in an importing country.

When quality of imported wheat was not fully observable, the importers' purchasing decisions were made by assessing the reputation of exporters. Firm-specific and country-specific reputation mechanisms were used to explain the exporters' behavior. It was hypothesized that importers relied more heavily on a country's reputation in the early 1980s, following the adoption of new wheat hybrids in many exporting countries. The variance of the estimate of the quality supplied by exporters was consequently higher, which forced importers to depend more on the country's reputation when assessing quality. This outcome may have induced individual U.S. exporting firms to exhibit free-rider behavior by lowering quality, since they each assumed that the remaining firms would maintain the country's reputation. Profit maximizing and large volume of exports were not necessarily compatible objectives.

The issue of licensing triple-m wheat varieties in Canada was also addressed. It was determined that when considering the exporters' and importers' ability to discriminate medium from high quality wheat, the benefits of licensing triple-m varieties has potentially been over-estimated in previous studies.
When assuming that importers have reservation quality levels and that quality is normally distributed, an increase in the variance of quality appeared to discourage (encourage) importers to import more wheat if the reservation quality level was below (above) the mean quality. Uncertain variance had similar effects. As in Das and Donnenfeld (1987), trade policies and exporters' choice of quality were analyzed. The results depended on what assumptions were made about both the importers' ability to obtain a discount for high variance and the exporters' cost function. In attempting to determine the effects of price uncertainty on quality mix, the results obtained were ambiguous except when the model was substantially simplified. In this instance, the variance of quality was removed and price uncertainty was shown to lower the volume and increase the mean quality of wheat. We can conclude that if final wheat prices were determined at the port of import, the exporters would face greater uncertainty and would upgrade the quality of their wheat.

Future Research

Unfortunately, empirical tests of the hypotheses suggested by this study could not be conducted. It is hoped that in the future a hedonic price index will be built in order to test whether or not U.S. wheat is
discounted with respect to wheat from other exporting countries. More work also remains to be done on price stabilization and quality. For example, more complicated models with more goods and factors of production should be built to capture the substitution between goods and factors when quality of the goods or factors vary.
REFERENCES


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Table A-1. Derivation of the determinant of equation (4-6) under assumptions that $U_1$ and $U_2 > 0$ and $U_{11}$, $U_{22}$, $G_y$ and $G_{yy} < 0$

\[
(U_{11}U_{22} - U_{12}^2)(G_y + P)^2 - 2U_{12}\text{cov}(U_{12}, q)(G_y + P)G_y \\
+ (U_{22}\sigma_q + \text{cov}(U_{22}, \sigma_q))(2U_{12}G_y + U_{22} + U_{11}G_y G_y) + U_{12}^2G_{yy} \\
+ U_{11}P^2G_{yy} - 2U_{12}G_{yy}P(U_{12} + \text{cov}(U_{12}, q)) + U_{11}U_{22}G_{yy} \\
- 2U_{22}\text{cov}(U_{12}, q)(G_y + P) + 2U_{11}\text{cov}(U_{22}, q)PG_y \\
+ 2U_{12}\text{cov}(U_{22}, q)(P - G_y) - 2U_{22}\text{cov}(U_{22}, q) \\
- (\text{cov}(U_{12}, q)G_y + (\text{cov}(U_{22}, q))^2)
\]
Table A-2. Derivation of the determinant of equation (4-15)

\[-(G_y+P)Q[U_{11}\text{cov}(U_{22}, q)P-U_{12}\text{cov}(U_{22}, q)+U_{22}\text{cov}(U_{12}, q)\]
\[-\text{cov}(U_{12}, q)\text{cov}(U_{22}, q)-U_{12}\text{cov}(U_{12}, q)]+(\text{cov}(U_{12}, q))^2PG_yQ\]
\[(G_y-P)[U_{22}U_{12}\sigma_q+U_{12}\text{cov}(U_{22}, \sigma_q)Q+U_{12}\text{cov}(U_{2}, q)]\]
\[(\text{cov}(U_{2}, q)+\text{cov}(U_{22}, \sigma_q)+U_{22}\sigma_q)(U_{22}-U_{11}G_yP)\]
\[+(\text{cov}(U_{22}, q))^2+\text{cov}(U_{2}, q)\text{cov}(U_{12}, q)G_y+\text{cov}(U_{2}, q)\]
\[\text{cov}(U_{22}, q).\]