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U.S. Competition of Hard Spring Wheat Characteristics

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U.S. COMPETITION OF HARD RED SPRING WHEAT CHARACTERISTICS

BY

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U.S. COMPETITION OF HARD RED SPRING WHEAT CHARACTERISTICS

This thesis is approved as a creditable and independent investigation by a candidate for the Master of Science in Economics degree and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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To God be the glory

Dedicated to life and the people I have had the privilege of sharing it with.

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ABSTRACT

U.S. COMPETITION OF HARD RED SPRING WHEAT CHARACTERISTICS

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There is a changing landscape in the wheat market from the emergence of foreign ownership of local elevators, increased consolidation in the milling sector, technology advancement, and changes in transportation. The changing landscape of the wheat market has been associated with greater degrees of vertical coordination through integration, strategic alliances, and contractual relationships. Particularly greater vertical integration has occurred between the millers, county elevators, and export and country terminal elevators. The greater integration of the milling sector has raised concerns by the Department of Justice Anti-trust division to the competitiveness of the flour market, and has only conditionally approved recent mergers. But the focus of this research is a preliminary study of marginal values for wheat characteristics to inform future research on measuring the effects of structural changes on marginal values. Since these changes to the wheat market structure have occurred, there has not been a recent hedonic study that has examined wheat characteristic values; even though it has been shown that marginal implicit values can be unstable over time since models are subject to both derived demand and supply. More importantly, wheat has a degree of site-specificity in that producers have high costs in marketing to alternative locations. Thus, this study examines hard red spring wheat marginal characteristics values using more recent data during these structural changes. Previous research on values of wheat characteristics was conducted in 1996, prior to many changes and integrations in the market landscape.

The hard red spring wheat (HRSW) region-North Dakota, South Dakota, Minnesota and Montana- is where we have observed the emergence of foreign ownership of facilities. Thus, a spatial dimension was added in the model by including inter-state (competition between states) and intra-state (competition between districts within a state) competition in HRSW quality characteristics.

The results suggest that protein is an important characteristic of HRSW with a premium of $0.308/bushel. Although this study indicates a higher marginal value of protein, it also shows a wider confidence interval for the marginal value of protein as compared to Parcell and Stiegert's estimates. The wider confidence interval found in this study indicates a greater uncertainty of premium values for protein. In addition, results indicate that premiums for protein and test weight for a specific district in a state can be affected by protein and test weight of other states. We therefore, conclude that discounts and premiums for HRSW characteristics in a specific district can be affected by the quality characteristics of other states; thus, indicating the importance of spatial competition for protein and test weight between states.

Wheat producers have to make important decisions about the varieties they will plant, the quality characteristics of the variety type; but also when to market their wheat depending on the quality characteristics and premiums being offered. A producer's objective is to maximize profitability of their operations, while mitigating financial risk. If protein premiums are volatile, then producers may be hesitant to adopt wheat varieties that have a higher probability of resulting in higher end-quality characteristics levels compared to yield benefits. This is particularly relevant when there are higher inputs costs to higher quality wheat and when there is great uncertainty to quality grades and premiums.

Producers' adoption of wheat varieties depends on their risk tolerance and tradeoff to yield versus quality characteristics. This is in contrast to wheat breeders' objective to optimize the balance for quality and yield for both producers and millers. Wheat breeders that develop varieties that enhance characteristics levels that are widely adopted across state lines can improve the average characteristic levels of a larger area and decrease the marginal value of that characteristic. However, if wheat breeders develop varieties that are adopted only locally, or even at a state level, there may not be an impact on the marginal value of the associated characteristics. Further, county elevators and terminal elevators have to keep quality wheat segregated from non-quality wheat during the storage and transportation processes. The objective of the terminal and county elevators for segregation may not be aligned with the millers' demand if there are not adequate premiums provided.

This research demonstrates the tradeoffs and risks that producers face with respect to wheat varietal selection decisions. Producers could explore hedging opportunities to manage price risk. Also, end-users that place a higher valuation on quality characteristics, could consider offering greater incentive mechanisms to producers and elevators that offset their risk associated to certain variety selections and maintain segregation. Challenges exist to achieve desired quality wheat attributes through breeding and management along with reducing environmental factors' influence on determining characteristic levels.

CHAPTER 1

INTRODUCTION

Statement of the Problem

The changing landscape in the wheat market, with the emergence of foreign ownership of local elevators and increased consolidation in the milling sector, produces a motivation to investigate whether the market has changed in how it signals the value of wheat characteristics. Since these changes to the wheat market structure have occurred, there has not been a recent hedonic study that has examined wheat characteristic values. It has been shown that marginal implicit values, parameter estimates, can be unstable over time since models are subject to both derived demand and supply. More importantly, structural changes in the supply chain can alter the price signal of how characteristics are valued due to site-specificity (Williamson, 1981) of wheat marketing.

The wheat market has exhibited a greater degree of vertical coordination through integration, strategic alliances, and contractual relationships altering the competitiveness within this market. The hard red spring wheat (HRSW) region has seen emergence of foreign ownership facilities. The concentration of the structural changes in the wheat sector is displayed in two ways. First, "increased consolidation may provide market power to acquiring firms" by Goodwin (1992) and Parcell, Mintert & Plain (2004) (as cited in Franken et al., (2005, p. 163). "Firms with market power are perceived to affect price levels, manipulating prices relative to other locations and reducing market efficiency" (Franken et al., 2005, p. 163). The introduction of new foreign elevator ownership may weaken the already existing price linkages; this is because existing elevators may already approximate perfect competition (Faminow & Benson, 1990). It can also lead to “structural shifts in these traditional grain movement patterns” (Bekkerman, 2013, p.5). Second, consolidation and the emergence of foreign ownership may improve market efficiency by decreasing transaction costs and increasing competition as stated by Goodwin & Schroeder (1991) (as cited in Franken et al. (2005, p. 163).

Bekkerman (2013) discusses the changing landscape of Northern Great Plains wheat markets, and explains that “long-run implications are less evident and may largely depend on the degree of oligopsony power - the acquisition of goods by few buying firms from seller - that may arise from changes in grain acquisition structures” (p. 3). Bekkerman (2013) further explains that the “result is market power consolidation among the fewer remaining facilities” (p. 3). One potential long-run implication of a higher concentrated elevator industry identified by Bekkerman (2013) is “changes in grain merchants pricing strategies” (p. 3). This could result in producers receiving a price lower than the competitive market equilibrium price and result in buyers being “slow or unresponsive in adjusting prices upward when fundamental conditions change” (Bekkerman, 2013, p. 3). However, as Sexton (2012) argues that the conceptual models of these typical market power studies assume a homogenous good. Sexton (2012) points out that wheat, especially, hard red spring wheat, is a highly differentiated product based heavily on protein content and test weight. Hard red spring wheat buyers are highly concerned about quality attributes due to its highly desirable milling properties. Sexton (2012) argues that we can see buyers in an oligopsony or monopsony market pay producers “as much or more than a competitive market price” in highly differentiated supply chains (p. 217). Sexton (2012) suggests that this is because those firms engage in "vertical coordination through contracts with significant transactions costs, and are committed to the future of the industry due to their sunk investment" (p. 217).

In addition, the wheat market has experienced changes in transaction costs over the past couple of decades that may have caused firms to consolidate and integrate. Transaction costs provide useful insights into the development of vertical coordination in the agricultural sector and it expanded from the works of Coase (1937). His focus was on costs of transacting in different organizational environments, mostly the cost of enforcing contracts. Coase argued that organization is established to minimize transaction costs of transacting business between two parties. Williamson (1981) defines that "a transaction occurs when a good or service is transferred across a technologically separable interface" (p. 552) He suggested that transaction cost analysis is about the "comparative costs of planning, adapting, and monitoring task completion under alternative governance structures" (Williamson, 1981, pp. 552-553). This theory presupposes that human agents are subject to bounded rationality, while others are given to opportunism. Williamson (1981) specifies that transaction costs can be measured based upon most importantly asset-specificity, frequency, and uncertainty. Williamson further defines asset specificity into three categories- site, physical, and human. Asset specificity is defined as "the extent to which the investments made to support a particular transaction have a higher value than if they are redeployed for another purpose" (McGuinness, 1994, pp. 66–81). Williamson argued that asset specificity is critical, in that, "once an investment has been made, buyer and seller are effectively operating in a bilateral (or at least quasi-bilateral) exchange relation for a considerable period thereafter" (Williamson, 1981, p. 555). Williamson (1981) also argued that the primary motivation for adopting different structures governing the contractual relationship between parties is because they want to economize transaction costs. He therefore, concluded that governance structures that have better transactional cost economizing properties will eventually displace those that have high transactional costs.

Transaction costs in the wheat industry indicate that buyers and sellers incur costs in conducting transactions. Those costs arise because of information asymmetry, bounded rationality and opportunism when the assumptions of perfect information are relaxed. Wheat production is highly site-specific because of its weather impact on growth which varies across years and location. The weather conditions during production and harvesting determines the quality of wheat in the period. For example, if it rains consistently across states in the U.S or some of the wheat growing countries, resulting in late harvesting, it can reduce protein, test weight, and increase damages and sometimes, shrunken and broken kernels. Weather conditions are site-specific and vary from year to year. This can create a competition between flour millers and bakers for high quality wheat to be utilized for milling purposes when weather conditions and other factors result in only a small, site-specific, location having high-quality wheat. Because domestic millers have preferences for particular varieties of wheat due to their milling or baking characteristics, one potential asset-specific investment would be the quality of the wheat utilized for milling purposes. The reason being that wheat quality determines the quality of flour used in production, so when the weather condition for wheat planting and harvesting are unfavorable, it affects millers. Hobbs and Young (1999) suggested that the degree of relationship risk depends mainly on the extent of asset specificity.

This changing landscape in the U.S. wheat market is a motivation to investigate whether changes in the market structure have potentially changed how the market values wheat characteristics. This study therefore examines hard red spring wheat marginal characteristics value with more recent data that encompasses these structural changes than the last research conducted in 1996. We added a spatial dimension in the model by including inter-state (competition between states), and intra-state (competition between districts within a state) competition in HRSW quality characteristics.

Several factors affect the price premium/discount (price differentials) of HRSW over other classes of wheat produced in the U.S. and the world. Quality characteristics of HRSW associated with end-use performance emphasize maintaining relatively high protein content and gluten characteristics. Quality characteristics are measured by physical characteristics such as protein content, moisture content, dockage, weight per bushel, damaged kernels, and foreign materials as a measure of premiums and discount. The differences in these quality characteristics are reflected in the U.S. classification system, which is part of the grades and standards used to describe quality.

Over decades, U.S. wheat quality has been under criticism for its reliability and consistency. Quality grades and standards[1] from the grain system are assigned to U.S. wheat as No. 1 - Highest quality down to U.S. No. 5 and U.S sample grades (Table 1-2). "The grade-determining factors are: test weight, heat damage, total damaged kernels, foreign material, shrunken and broken kernels, total defects, wheat of other classes, contrasting classes, and sample grade criteria. The other required factors which are non-

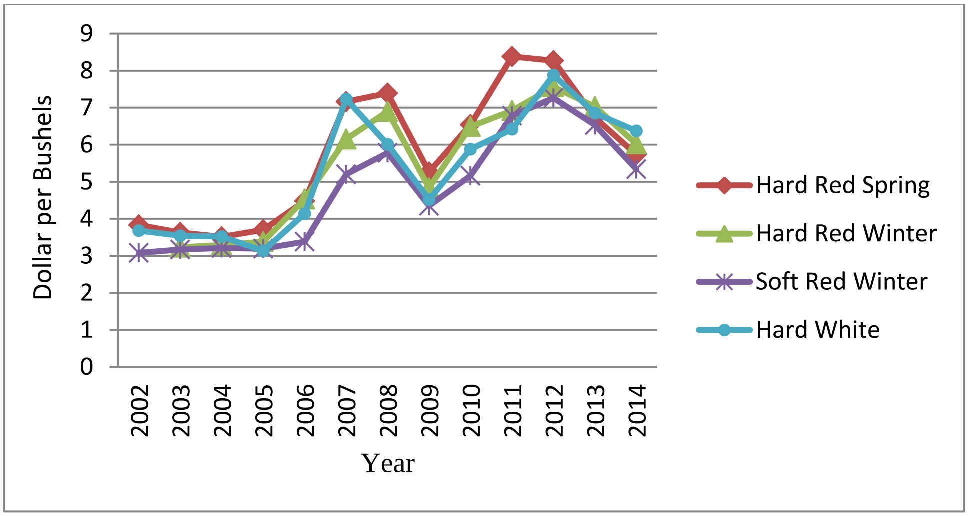
[1] U.S. Quality grade and Standard was established by the Federal Grain Inspection System (FGIS) in the early 1900's.

grade-determining are wheat class, dockages, and moisture" (US Wheat Associates, 2007, p.14). The grading system serves as a means for transmitting quality information on wheat characteristics (USDA Grain Inspection, 2006). The US Wheat Associates (2002), however, indicated a growing concern about maintaining supply reliability and consistency in wheat produced and imported from the United States.

The precise mentioned points, quality characteristics and grading requirements, play a very significant role in determining the implicit value of HRSW characteristics. Marginal implicit values are a function of prices and quality characteristics estimated using a hedonic price model. Implicit values are the premiums or discounts in prices of wheat when there is a change in the marginal level of wheat characteristics based on differences in variety, quality and physical attributes. The commercial standard for HRSW specification is 13.5% protein (although 13.0% protein may be delivered at a discount) because HRSW is a premium milling quality wheat (Minneapolis Grain Exchange, 2011). The differences in wheat characteristics reflect the end-user value of certain characteristics and influences price linkages in the world wheat market. Figure 1-1 shows national U.S. prices of the different wheat classes from 2002 to 2014; it shows that wheat prices were not constant over time with fluctuations between 3 to 8.3 dollar per bushels during the period observed. For a detailed explanation on the classes of wheat produced in U.S. and the world, see appendix *B*[2]. Figure 1-1 also reveals that on average there is an increase in wheat prices for all the wheat classes. In 2006 and 2008/09, there

[2] Appendix B will provide further background information on U.S. and world wheat production, exports, and imports. It also provides a historical perspective of U.S. hard red spring wheat planted and harvested acres.

was reduction in prices for all the classes of wheat due to the World Economic Crisis in 2008/09.



Source: National Agricultural Statistics Service

Figure 1-1: National U.S. Wheat Prices of the Different Wheat Classes

The differences in wheat prices are attributable to protein and color. Protein content has been the main determinant of end-use performance and hardness. Thus, while the correlation between higher protein and end-use quality depends on protein quality (proxy for baking and milling), that of hardness is highly correlated with protein levels and types. Changes in these characteristics can either be a premium relative to a base bushel of HRSW (positive parameter) or discount relative to a base bushel of HRSW (negative parameter). Therefore, determining the premiums or discounts related to these characteristics is important to farmers, producers, and marketing decision makers.

These factors influence the demand for wheat and most importantly its suitability for end-users determined by the quality characteristics it possesses. Currently, there is inadequate information on the values of wheat quality characteristics in the United States. Adequate information on wheat quality is of great importance to producers, farmers and marketing decision makers. Thus, quality characteristic values provide signals to producers and industry personnel of the most demanded characteristics from an end-use perspective.

Purpose of Study

The South Dakota Agricultural Experiment Station is a scientific research center that investigates difficulties and potential improvements to food production and agribusiness funded partially by producers' checkoff programs. In an attempt to maintain high quality and yield potential, university breeders work to develop variety lines that are suited to the climate of specific regions in order to optimize yield and quality wheat factors. For producers to make optimal decisions about varietal selection concerning yield and quality, it is important to know the value of quality characteristics. The results of this study will be valuable to producers and all individuals along the wheat supply chain. It will provide recommendations for producers and plant breeders to invest in techniques and breeds that enhance the characteristics most demanded by the market.

Background

The wheat market has begun to see an emergence of foreign ownership of local elevators, increased consolidation in the milling sector, technology advancement, and changes in transportation. The wheat market has also exhibited a greater degree of vertical coordination through integration, strategic alliances, and contractual relationships altering the competitiveness within this market. Structural changes in market dynamics can impact how characteristics are valued. Segments along the wheat supply chain are interested in the changing trends that most influence profit and productivity such as foreign ownership in exporting countries by importing countries, and transportation costs. This changing landscape in the U.S. wheat market is a motivation to investigate whether changes in market structure has changed how the market values wheat characteristics.

Historically, producers sold their grain to mostly local independently operated grain-handling facilities, which then marketed the grain for rail transport (transportation of choice) to the principal market, Minneapolis Grain Exchange or another terminal market. However, agriculture has changed with advanced technologies such as tractors on autopilot, irrigation via smartphone, field documentation, biotechnology, and sensors for obtaining crop data, and so has the transportation industry with automated handling, freight modes, and export processes that differ greatly from the traditional marketing structure (Bekkerman, 2013). Such changes are part of a technology revolution, that is changing the way farmers and ranchers do business. These changes also directly affect policy and market events.

First, the U.S. flour milling industry has seen more consolidation and the wheat industry has seen more multi-national companies taking ownership of local elevators making significant investments in these facilities. Between 2000 and 2012 Japan and South Korea have taken ownership of various facilities in order to source high quality wheat for their end-uses. There are years when there is a shorter supply of high quality (high protein) wheat. So, as the wheat importing countries assume more ownership in the United States at a local level, they can gain more control over pricing and obtain high quality wheat, as well as control management decision at facilities, such as what degree of protein level segregation to maintain.

Japan is one of the largest buyers of U.S. hard red spring wheat. Over the decades, Japan has purchased significantly more U.S. wheat than any country in the world, importing on average 3.17 million metric tons per year (Prairie Grains, 2011). Japan imports significant amounts of hard red spring wheat, hard red winter wheat and soft white wheat for the production of noodles, bread, and other commercial products. They also have advanced milling and baking industries that rely on U.S. Wheat Associates (USW) for the information they need to meet strict quality and safety requirements (Prairie Grains, 2011).

Table 1-1 reports on the percentage of value of shipments and value added accounted for by the 4-, 8-, 20-, and 50- largest companies for each manufacturing industry. Also shown in the table are Herfindahl-Hirschman indexes for each industry. The total value of shipment used in the table includes the received or receivable net selling values of all products shipped, both primary and secondary, sales of scrap and sales of products bought and sold without further processing, as well as all miscellaneous receipts such as, receipts for contract work performed for others installation and repair. As shown in Table 1-1, changes in the flour milling industry have steadily progressed since the 1970s. The total value of shipments has increased more than four times from 1970 to 2007. Market concentration of four firms for the time period from the 1970s/1980s to 1990s/2000s increased from 34% to 53%, while that of Herfindahl-Hirschman Index increased from 551 to 829 within the same time frame. This indicates that there that been increased consolidation in the flour milling sector.

Table 1-1: Flour Milling from 1970 to 2007

Year	Total value of shipments (million dollars)	Percent of total value of shipments				Herfindahl Herschmann index for 50 largest companies[3]
		4 largest companies	8 largest companies	20 largest companies	50 largest companies	
1970	2410.1	30	46	x[4]	x	x
1972	2380.0	33	53	75	91	x
1977	3683.3	33	54	76	91	x
1982	4932.8	40	60	78	94	551
1987	4984.8	x	x	x	x	x
1992	6294.4	56	68	83	95	972
1997	8001.9	48.4	62.5	79.2	93.4	699.6
2002	6840.8	53.6	67.4	82.1	94.4	812.3
2007	9812.5	54.5	67.7	82.9	95.5	831.3

Source: **U.S. Census Bureau Economic Census**

Additional evidence of the consolidation is demonstrated by a newly developed joint venture flour milling company, Ardent Mills (ConAgra Foods, Cargill, and CHS) in 2014. The formation of Ardent Mills, which would become the nation's largest flour miller, could only be allowed to proceed if the companies involved sold four competitively significant mills as ruled by the U.S. Justice Department (Pankratz, 2014, paragraph 1). Ardent Mills brings together two of the nation's leading and most respected flour milling companies: ConAgra Mills and Horizon Milling (Cargill-CHS joint venture formed in 2002) in May 29, 2014. "The new company took advantage of the combined assets, capabilities and experience of ConAgra Foods, Cargill and CHS to bring innovative flour and grain products, services and solutions to the marketplace" (Cargill,

[3] Herfindahl-Hirschman Index is a measure of market concentration. It is calculated by squaring the market share (concentration ratio) of each firm competing in a market, and then summing the resulting numbers

[4] x – Not Applicable

2014, paragraph 2). They "offer a unique set of services including product development resources, technical and application support, supply chain management and commodity price risk management" (Cargill, 2014, paragraph 2). They also "tap the market knowledge, transportation logistics, consumer insight and wheat sourcing capabilities" (Cargill, 2014, paragraph 2).

Ardent Mills operates as an independent joint venture of its three parent companies, Omaha, Neb.-based ConAgra Foods, Minneapolis, Minn.-based Cargill and St. Paul, Minn.-based CHS with Denver being the headquarters (Cargill, 2014, paragraph 2). In addition to its headquarters, Ardent Mills operates satellite offices in Omaha, and Minneapolis (Pankratz, 2014, paragraph 4). ConAgra Foods and Cargill each own a 44 percent stake in Ardent Mills, and CHS would own 12 percent interest (Pankratz, 2014, paragraph 8). All three companies have representatives on Ardent Mills' board of directors (Cargill, 2014, paragraph 2). This change might be more acute in some parts of the country where Horizon mills and ConAgra mills compete directly for business but under the merger, they would be owned by the same entity. The joint venture controls 41 percent of the U.S. wheat milling capacity (Federal Register, 2014).

In the complaint, the Department of Justice alleged that the proposed joint venture would eliminate head-to-head competition between ConAgra Mills and Horizon Milling in the relevant markets resulting in higher hard wheat flour prices for customers in Northern and Southern California, as well as Northern Texas and the Upper Midwest (Federal Register, 2014; Pankratz, 2014). The merger was also predicted to result in higher soft wheat flour prices for Southern California and Northern Texas customers (Federal Register, 2014). Forecasters expected a reduction in flour milling capacity

(Federal Register, 2014). They also predicted anticompetitive coordination among flour millers. The Final Judgment prohibited the three parent companies from disclosing to Ardent Mills certain non-public information relating to wheat sales and wheat used by their customers, due to confidentiality agreements with Ardent Mills (Cargill, 2014; Federal Register, 2014; Pankratz, 2014).

Finally, another motivating factor is to provide transparency on the valuation of wheat characteristics through the findings of this research. This information can be used by individual end-users to either validate the wheat characteristic valuations or to show that the market is not effectively communicating the characteristic valued to end-users. If the market doesn't effectively share end-user characteristic valuation through the supply chain to producers, then one possible reason could be the differentiation in quality characteristics for wheat or the grading system doesn't align with the specific preferences of wheat buyers. This may result in wheat buyers adopting contracting or possibly vertically integrating in order to obtain product that meet their specific demands.

U.S. Wheat Industry

Wheat is a cereal crop that can be classified into five major classes. These five wheat categories are comprised of: hard red winter (HRW) wheat, hard red spring wheat (HRSW), soft red winter (SRW), white, and durum wheat. Each class has a different end-use and the cultivation tends to be region-specific. Hard red winter wheat is a dominant class of wheat in the U.S export market and the largest class of wheat produced every year. It is mainly cultivated in the Great Plains area ranging from Montana to Texas. Hard red spring wheat is mainly grown in the Northern Plains areas (Montana, North

Dakota, South Dakota and Minnesota) and is mainly used for protein blending purposes. Durum wheat is primarily grown in the North Dakota and Montana. Almost every U.S. state is involved in agricultural wheat production. The latest statistics show that North Dakota (273; 347 million bushels), Kansas (321; 246 million bushels) and Montana (202; 209 million bushels) were the leading wheat producing states among the United States between 2013 and 2014.

Grading Requirements

The USDA Grain Inspection, Packers and Stockyard Administration (GIPSA) define wheat grades to reflect the general quality and condition of a representative sample. The grades are based on test weight, damaged kernels, foreign material, shrunken and broken kernels as well as wheat of different classes. The five U.S classes of wheat produced and exported are based on color and kernel as well as other characteristics. There are five U.S. numerical grades and U.S. Sample Grades where each class and sub-class of wheat resides (Table 1-2). The U.S Sample Grade is a type of grade where wheat does not meet requirements for grades U.S. No.1, 2, 3, 4 and 5 and other characteristics. There is also a special grade allocated to wheat with special qualities, but this does not affect the numerical grading system. The grading requirement helps end-users know the difference in quality characteristics for each class of wheat.

Table 1-2: Wheat Grades and Grade Requirements

Minimum Limits of -			Maximum Limits of -						
	Test Weight per bushel		Damaged Kernels				Wheat of other classes **2/**		
Grade	Hard Red Spring Wheat or White Club Wheat (pounds)	All other classes and subclasses (pounds)	Heat damage (part of total) (percent)	Total (percent)	Foreign material (percent)	Shrunken and broken kernels (percent)	Defects **1/** (percent)	Contrasting classes (percent)	Total **3/** (percent)
U.S. No.1	58.0	60.0	0.2	2.0	0.4	3.0	3.0	1.0	3.0
U.S. No.2	57.0	58.0	0.2	4.0	0.7	5.0	5.0	2.0	5.0
U.S. No.3	55.0	56.0	0.5	7.0	1.3	8.0	8.0	3.0	10.0
U.S. No.4	53.0	54.0	1.0	10.0	3.0	12.0	12.0	10.0	10.0
U.S. No.5	50.0	51.0	3.0	15.0	5.0	20.0	20.0	10.0	10.0

Source: Adapted from USDA Grain Inspection, Packers and Stockyard Administration (GIPSA)

Global Wheat Industry

Different classes of wheat are produced and traded in the world wheat industry. These classes of wheat are differentiated based on characteristics such as color, protein level and quality, kernel hardness, grade factors, moisture content and test weight (Table 1-3). Planting time is another important feature of wheat varieties. Every country has its own planting and harvesting period for the various classes of wheat. For example, in the United States, winter wheat is planted from mid-August through October and harvested from mid-May to mid-July, while spring wheat is planted from April through May and harvested from mid-August to mid-September.

Table 1-3: Description of Major Types of Wheat

Wheat Type	Class	Protein (%)	Moisture (%)	Test Weight	End Product
Argentinean Trigo Pan wheat	Medium-Hard Spring wheat	10	14	60	Bread and Rolls
Australian Standard White wheat	Medium-Hard White wheat	9.2 9.6	12	65.5	Flat Bread and Noodles
Canadian Western Red Spring wheat	Hard-Spring wheat	12.5	13.9	58-60	Bread
US Dark Northern Spring wheat	Hard-Spring wheat	14	12	60	Pasta Products
US Hard Red Winter wheat	Medium-Hard Winter wheat	11.5	12.2	59.6	Bread rolls and all-purpose Flour
US Soft Red Winter wheat	Soft-Winter wheat	10	13	57.5	Biscuits, Cakes Crackers, Pastries
US Western White wheat	Blend of Soft White & Common wheat, Winter wheat	9	9.5	60.4	Biscuits, Cakes and Crackers
EU Standard Wheat	Soft Winter wheat	10.5	15	59	Bread, Crackers

Source: Adapted from Halverson, Zeleny, and Pomeranz (1988) in Morris and Rose (1996) and Kettlewell (1996) in Ghoshray (2002)

Hard Red Spring Wheat (HRSW)

Hard red spring wheat is a specialty wheat because of its high protein and strong gluten characteristics over other classes of wheat. This high quality wheat is grown primarily in the North Central United States, which includes North Dakota, South Dakota, Montana, and Minnesota. It has high protein content of 13% - 14%, greater gluten quality content and good milling and baking characteristics used for specialty breads and blending with lower protein wheat.

Spring wheat is classified into sub-classes (dark northern spring, northern spring and red spring) based on the dark, hard and vitreous kernel contents. It is planted in the spring (April through late May) and harvested in late summer (August to mid-

September). U.S hard red spring wheat is traded on the Minneapolis Grain Exchange, established in 1881 as a cash market for grains and has the largest wheat futures and option contracts based on its unique characteristics such as protein, and test weight (Minneapolis Grain Exchange, 2011). Among the producing states are North Dakota, Minnesota, Montana, and South Dakota as well as Idaho, Oregon and Washington. Table 1-4 shows the HRSW production for the top producing states from 2010 to 2014.

Table 1-4: U.S. Hard Red Spring Wheat Production by States (Million Bushels)

States	2010	2011	2012	2013	2014
Minnesota	87.8	70.2	76.4	67.2	66.5
Montana	214.2	175.0	195.6	201.6	209.5
North Dakota	356.6	199.9	340.1	273.3	347.1
South Dakota	122.6	103.9	102.0	77.6	131.3
Total Production	781.2	549.0	714.1	619.6	754.4

Source: National Agricultural Statistics Service (NASS)

Objectives

The general objective of this study is to find out the marginal implicit values of HRSW characteristics and spatial quality levels for HRSW growing regions. Specifically, we

- Examined the influence of other districts within a state level concerning characteristics and their influence on marginal values and
- Examined the influence of other states level of characteristics and its influence on marginal values.

CHAPTER 2

REVIEW OF RELATED LITERATURE

Introduction

The purpose of this chapter is to review literature related to the hedonic price model or characteristic approaches that have been presented to model wheat demand and supply, with particular emphasis on hard red spring wheat.

Hedonic Price Models

Numerous studies have used the hedonic price model to examine the characteristics of wheat. These studies have varied in the type of wheat or by region examined. In addition, studies have explored the influence of flour, a processed product of wheat characteristics, on wheat prices. Reviews of previous studies are organized according to the study's area of focus, ranging from international to U.S. wheat markets.

In the international wheat market, protein and test weight are an important quality characteristics of wheat in export markets. Export level premiums and discounts of wheat have been widely studied by Veeman (1987), Wilson (1989), Larue (1991), Ahmadi-Esfahani and Stanmore (1994) and Uri, Hyberg, Mercier, and Lyford (1994). Specific characteristics of wheat that are analyzed when considering export quality include protein, test weight, shrunken and broken kernels and damaged kernel content.

Veeman (1987) used the characteristic approach to estimate implicit values of protein for the Canadian Western Red Spring (CWRS) wheat over other classes of hard wheat. Veeman found that a 1% increase in protein content was associated with an average 0.32% price premium from 1976/77 to 1979/80. Also, from 1980/81 to 1983/84 their results showed a 1% increase in protein was associted with an average price premium of 0.47%. Veeman also found that there was a $6 metric tons (MT) premium for a 1% increase in protein in world prices for the time period 1976 to 1984. These price increases were in response to the impact of global recession.

Wilson (1989) examined the implicit value of protein varying according to origin and destination location. Wilson found that a 1% increase in protein content is associated with $3.13/MT in Japan market, $21/MT in Holland market, and $8.18/MT in the U.S. Pacific Port. Wilson suggested that differences in processing technology and types of products produced were a potential reason for this increase in Japanese premiums. He also identified a small but increasing premium for hard wheat of $2/ton in the mid-1970s and $3/ton in the mid-1980s.

Larue (1991) examined the relationship between wheat and flour characteristics and the value of individual wheat characteristics. Results showed that there is a high correlation between wheat and flour characteristics. This implies that wheat characteristics entering most grading systems provide useful information about flour quality and flour yield. Also, the correlation between wheat characteristics and wheat prices using a hedonic price model establishes that protein content is a very important quality criterion. Larue reported a significant value for protein; thus, a $5.49/ton premium for high protein wheat contrasted with a $1.65/ton premium for both medium protein and for low protein, while test weight was insignificant. He then concluded that because the implicit values of quality characteristics varied according to end-use, wheat purchased for different uses should be considered as different products.

Uri et al. (1994) examined individual wheat export transactions and found that implicit values for quality characteristics changed over time with no uniform pattern and were different across wheat types. For example, protein premiums for HRSW was $14.14/MT. Ahmadi-Esfahani and Stanmore (1994) explored the implicit values of protein in Australia wheat and found that there was a premium of $8.18/MT for each additional percent of wheat protein content and an average of $5.34/T premium for additional percent of flour protein content.

Other studies such as Stiegert and Blanc (1997) have estimated the effect of FGIS grades and protein content on prices across time and in different markets. Stiegert and Blanc used an extension of the hedonic price model from Land and Martin to analyze the marginal value of wheat protein for Japanese imports. They identified a $4.75 to $5.75 premium for a marginal change in protein content. Also, they found a positive relationship between protein value and dough stability leading to higher marginal values for higher protein levels as compared to lower protein levels. They concluded that the role of protein in dough stability, extensibility and absorption resulted in different values for wheat for different end-use products.

All these studies have pointed out the significance of quality wheat characteristics, mainly focusing on protein content from the world perspective. Their results pointed out the significant role of protein in wheat production that end-users desire. Protein content was found to be positively significant as anticipated in the studies. Although flour characteristics are not the major priority of this study, the studies of Larue (1991), which identifed a high correlation between wheat and flour characteristics, provides useful information about flour quality and flour yield through wheat characteristics. Thus, the quality of flour obtained by end-users would depend on the quality of wheat characteristics after processing. We therefore assume that wheat characteristics are correlated with flour characteristics in this study. This means that desirable wheat characteristic values implicitly represent valued milling characteristics to some degree.

Given the importance of wheat characteristics, especially in the United States wheat market, several papers have focused on quality characteristics, consistency and baking characteristics in the U.S market. Bale and Ryan (1977) analyzed the relative price effects caused by changes in available supplies of wheat with various protein contents. They found that spring wheat supply had the highest level of significance and was positively related to price. They also found that increased supplies of protein in the HRW crop caused a shift in the HRS demand curved. Bale and Ryan concluded that protein supplies in the HRS crop were more closely associated with changes in the HRS price ratios.

Only a few previous studies have included end-use performance to their model and Espinosa and Goodwin (1991) is an example. Espinosa and Goodwin (1991) studied premiums and discounts at the farm level for Kansas wheat charactersitics using a hedonic model. They found that prices received by Kansas wheat farmers were significantly influenced by the standard (conventional) grading characteristics and alternative end-use quality characteristics. Thus, prices were responsive to quality variables and any additional percent increase in protein was associated with a $0.0492 per bushel premium. Espinosa and Goodwin (1991) also indicated that alternative characteristics exhibit quality information that is independent of one another to some degree. They concluded that wheat prices are responsive to differences in the quality of wheat.

In this paper, we move beyond previous studies by directly looking at the quality characteristics of HRSW by following Parcell and Stiegert (1998) using the hedonic price model. In the Parcell and Stiegert paper, they estimated the marginal implict value of wheat characteristics in a spatially competitve framework using data from Kansas Wheat Quality Report series and the Regional Hard Red Spring Wheat Quality Report series. A demand characteristics system was modeled to include an interaction term which captures the changes in marginal value of each characteristic as the supply of those characteristics changes between wheat classes and within the same wheat class. Two classes of wheat were considered- North Dakota Dark Northern spring wheat (DNSW) and Kansas hard red winter (HRW), but only the DNSW results were compared to the results of this study in order to make comparisons within the HRSW type. Parcell and Stiegert's results indicated that the marginal value of protein for DNSW was affected by the level of protein in other regions. They also found protein to be statistically significant with marginal value of $0.169/bushel for DNSW. Considering that premiums for specific quality characteristics might be affected by the production-weighted values of the same characteristics in other districts in the same state, the intra-regional effects were estimated. They also estimated the inter-regional effect on premiums of the value of characteristics in a different state. DNSW protein was shown to have statistically significant negative inter-regional effect on price. Results on DNSW showed that marginal value of protein for inter-regional effect was -$0.007/bushel. The marginal value of DNSW test weight was $0.098/bushel, while the intra-regional effect was statistically significant indicating a negative relationship with price. Thirty-two percent of the DNSW marginal values for damaged kernels were statistically significant. They concluded that wheat values were determined by both demand and supply of each characteristic.

This research uses the same type of hedonic price model and procedures as presented in the Parcell and Stiegert (1998) paper simply because it is the only paper that incorporates U.S. domestic wheat spatial competition. There are several deviations from the Parcell and Stiegert paper that makes this thesis unique on its own. First of all, the type of wheat examined in this study was hard red spring wheat (HRSW) and its spatial competition covers four growing states, North Dakota, South Dakota, Montana and Minnesota. The Parcell and Stiegert paper examined two types of wheat – HRW wheat from Kansas and North Dakota spring wheat (DNS) from North Dakota. Also, both studies added a spatial dimension in the model. While Parcell and Stiegert defined the spatial component from the regional perspectives, this study defines it from the state perspective. The spatial competition in this study looks at two interaction variables – inter-state effect and intra-state effect. Intra-state describes the spatial competition of quality characteristics between districts within a state. The intra-state term will capture the production-weighted level of characteristics influence of other districts within an own district's state exclusive of the own district. Inter-state refers to the spatial competition of quality characteristics between states. Inter-state effects refer to the impact of wheat quality exclusive of the own district's state on prices in that district's state. In terms of the location dummy variables, Parcell and Stiegert used regional level dummy variables, while this study uses district level dummy variables. Another unique aspect about this study is the time period; thus, it uses HRS wheat characteristics and prices from 1998 through 2012, unlike the Parcell and Stiegert paper where the data period was 1974 – 1996.

Conclusion

The literature review signifies that implicit prices found by using price and quality data shows significant importance and value of characteristics to the overall prices of wheat classes. This study examines the U.S. competition of HRSW characteristics in the four growing states using a hedonic price model. Although the effect of wheat characteristics and quality levels for the various classes of wheat have been extensively studied, little attention is given to cross-regional competition for the HRSW characteristics. The motivation for this model is based on Rosen's theoretical framework for identifying characteristics demand parameters and its application by Ladd and Martin (1976).

The study provides information that could improve the U.S. grading system, so it accurately conveys quality characteristics to buyers. It will also help producers and plant breeders to invest in techniques and breeds that enhance the characteristics most demanded by the market place. Hence, this study seeks to examine the effect of wheat characteristics and spatial quality levels for the Upper High Plains HRSW growing region.

CHAPTER 3

CONCEPTUAL AND EMPIRICAL MODEL

Introduction

This chapter reviews the conceptual framework and empirical model that describes the marginal values of hard red spring wheat characteristics. The first set will review economic theoretical background and mathematical derivation of the hedonic model, and the second set will outline the empirical model used in the study.

Conceptual Framework

Wheat market participants may consider sampling wheat production in states to know the quality of wheat being produced in a state in any given marketing year. The competition for these wheat quality characteristics means that some states receive implicit premiums, while others receive implicit discounts based on the relative scarcity of quality characteristics in a given state.

This study uses the method developed by Rosen (1974) and Lancaster (1971) based on demand for quality characteristics. But its application was outlined by Waugh (1928) and Court (1939), with Court being the first to use the term "hedonic" in his studies - Hedonic Price Indexes. Later Ladd and Martin (1976) and Ladd and Suvannunt (1976) adopted the general theory of hedonic analysis and applied it in the agricultural sector.

Following the mathematical derivation of Ladd and Martin's (1976) theoretical model, the first step is to define the variables of the framework as follows:

v_{ih} = the quantity of the i^{th} input used in production of h^{th} product

r_i = the price paid for the i^{th} input

P_h = the price received for product h

q_h = the quantity of the h^{th} output produced

x_{jih} = the amount of characteristics j provided by one unit of input i into production of product h

$x_{j.h}$ = the total quantity of characteristics j that enters into production of product h.

This framework assumes that the values of x_{jih} are parameters that the producers cannot control. Relating the price paid for a bushel of HRSW to the values of the marginal yields of the bushel's characteristics. The production function for product h is expressed as:

Equation (1) $$q_h = F_h\left(x_{1.h}, x_{2.h}, ..., x_{m.h}\right).$$

Equation 1 states that the output of product h is influenced by the quantities of input characteristics used in production. The total quantity of each characteristic are expressed as a function of input quantities and the amount of the characteristic provided for each input. The characteristic quantity is therefore defined in Equation 2 as:

Equation (2) $$x_{j.h} = X_{jh}\left(v_{1h}, v_{2h}, ..., v_{nh}, x_{j1h}, x_{j2h}, ..., x_{jnh}\right) .$$

The production function can be written as, Equation (3) $$q_h = G_h\left(v_{1h}, v_{2h}, \ldots, v_{nh}, x_{11h}, x_{12h}, \ldots, x_{mnh}\right) \; .$$

The model then assumes that the firm is a profit maximizing firm with its profit function written as Equation 4:

Equation (4) $$\pi = \sum_{h=1}^{H} p_h F_h\left(x_{1.h}, x_{2.h}, \ldots, x_{m.h}\right) - \sum_{h=1}^{H}\sum_{i=1}^{n} r_i v_{ih} \; .$$

Because F_h is a function of the $x_{j.h}$ and the $x_{j.h}$ are functions of v_{ih}, to differentiate Equation 4 with respect to v_{ih}, we use a function of functions rule (Ladd and Martin, 1976). According to this rule,

Equation (5) $$\frac{\partial F_h}{\partial v_{ih}} = \sum_j \left(\frac{\partial F_h}{\partial x_{j.h}}\right)\left(\frac{\partial x_{j.h}}{\partial v_{ih}}\right).$$

Using this expression in differentiating Equation 4 (first-order-condition) yields:

Equation (6) $$\frac{\partial \pi}{\partial v_{ih}} = p_h \sum_{j=1}^{m} \left(\frac{\partial F_h}{\partial x_{j.h}}\right)\left(\frac{\partial x_{j.h}}{\partial v_{ih}}\right) - r_i = 0 \; .$$

Rearranging Equation 6 to solve for r_i can be expressed as,

Equation (7) $$r_i = p_h \sum_j \left(\frac{\partial F_h}{\partial x_{j.h}}\right)\left(\frac{\partial x_{j.h}}{\partial v_{ih}}\right).$$

$\partial x_{jh} \big/ \partial v_{ih}$ is the marginal yield of characteristic j to production of the h^{th} product from the i^{th} input ; $\partial F_h \big/ \partial x_{j.h}$ is the marginal physical product from a unit of characteristic j used to produce the h^{th} product; and $p_h \, \partial F_h \big/ \partial x_{j.h}$ is the value of the marginal product of j^{th} characteristic used in the production of h. It can be interpreted as the marginal implicit (or imputed) price paid for j^{th} product characteristic used in product h (Ladd and Martin, 1976). This let $p_h \frac{\partial F_h}{\partial x_{j.h}} = T_{jh}$, where Equation 7 can be written as:

Equation (8) $$r_i = \sum_j T_{jh} \left(\frac{\partial x_{j.h}}{\partial v_{ih}} \right).$$

where $T_{jh} \left(\frac{\partial x_{j.h}}{\partial v_{ih}} \right)$ is the value of the marginal yield of the j^{th} characteristic by using the i^{th} input in production of output h (Ladd and Martin, 1976). It is assumed that $\left(\frac{\partial x_{j.h}}{\partial v_{ih}} \right) = x_{jih} =$ constant and $T_j =$ constant. This allows for the creation of Equation 9. This means that the yield of each characteristic by an input is not affected by the use of the input (Ladd and Martin, 1976). When applied to this study, an additional pound of nitrogen will have the same yield across wheat locations. Where Equation 9 is defined as,

Equation (9) $$r_i = \sum_j T_{jh} x_{jih} \ .$$

However, the marginal implicit value T_{jh} need not be constant. Ladd and Martin showed that if Equation 7 is derived from a functional form with its characteristics j in a quadratic form, then the price r_i would depend on the level of wheat characteristics at each observation.

Another important aspect of this paper is determining the inter-state and intra-state effects of HRSW characteristics. Intra-state effects refer to the impact on price in one district[5] from changes in wheat quality in other districts within one district's state. Inter-state effects refer to the impact on price in one state from changes in wheat quality in other states. We, therefore consider how changes in the level of a characteristic in producing states affect the value of quality characteristics in a particular state. This is because when a state is unable to supply an adequate amount of wheat with high quality characteristics, wheat participants may look to other states to source its supply. For example, suppose the North Dakota HRSW price r_i depends on protein availability in both the North Dakota production (x_{11}), South Dakota production (x_{12}), Minnesota production (x_{13}) and Montana production (x_{14}). The Equation 9 derived – price of a bushel of HRSW in North Dakota could be specified in a linear form to account for spatial competition amongst the protein characteristics,

Equation (10)

$$r_i = \beta_1 x_{11} + \beta_2 \left(x_{11} * x_{12} \right) + \beta_3 \left(x_{11} * x_{13} \right) + \beta_4 \left(x_{11} * x_{14} \right) = x_{11} \left(\beta_1 + \beta_2 x_{12} + \beta_3 x_{13} + \beta_4 x_{14} \right),$$

where: β_1 represents the estimated parameters relating changes to North Dakota HRSW protein content to North Dakota HRSW price; β_2 represents coefficient relating changes in the South Dakota and North Dakota HRSW protein content to North Dakota HRSW prices; β_3, is the parameter estimate relating changes in the Minnesota and North Dakota protein content to North Dakota HRSW price; β_4 is the parameter estimate relating changes in Montana and North Dakota protein content to North Dakota HRSW price; and, $\left(\beta_1 + \beta_2 x_{12} + \beta_2 x_{13} + \beta_2 x_{14} \right)$ is the marginal implicit value of protein in North Dakota, which varies with the level of protein in South Dakota, Minnesota, or Montana

[5] See appendix for graphs on how the districts are defined for each state.

HRSW. Parcell and Stiegert (1998) used a similar approach to estimate for the intra- and inter-regional quality characteristics competition.

Empirical Model

In accordance with the literature and to remain consistent with the study objectives, the study uses a hedonic price model to estimate the marginal implicit values of HRSW characteristics both intra-state and inter-state. The relationship between prices of different classes of wheat and quality characteristics under several hedonic price models show that protein is the most significant factor influencing the price of different classes of wheat. Other wheat characteristics such as shrunken/broken kernels and damaged kernels are controlled at the terminal elevators through cleaning and screening processes (Parcell & Stiegert, 1998). Their estimation is not expected to determine prices across each state, but could be factors in explaining prices within each state because farmers have far less ability to control these characteristics, and elevators are likely to pay higher prices for wheat with lower handling costs.

For simplicity, we used the term intra-state effects to describe spatial competition between districts within a state and inter-state effects to describe spatial competition between states. As shown in equation 11, intra-state effect is represented with "od", example, protein is ptxptod and inter-state effects are represented with "os", example, protein is ptxptos. And in chapter 5, results and discussion, is explained in words as "other districts' *X* district" for intra-state competition and "other states' *X* district" for inter-state competition. The quality characteristics value is determined by demand and supply. Parcell and Stiegert (1999) used the same approach to account for inter- and intra- regional effect of wheat quality characteristic competition. Therefore, this study models these characteristics spatially by following the conceptual framework of Ladd and Martin (1976) and the procedure of Parcell and Stiegert (1999).

The hedonic equation to be estimated is Equation 11,

$$Price_{i,t} = \beta_0 + \sum_{i=2}^{19} \gamma_i district_i + \sum_{t=2}^{15} \delta_t year_t + \beta_1 protm_{i,t} + \beta_2 ptxptod_{i,t} + \beta_3 ptxptos_{i,t} + \beta_4 twtm_{i,t} + \beta_5 twtxtwtod_{i,t} + \beta_6 twtxtwtos_{i,t} + \beta_7 sbm_{i,t} + \beta_8 sbxsbod_{i,t} + \beta_9 damm_{i,t} + \beta_{10} damxdamod_{i,t} + e_{i,t},$$

where subscript i refer to the i^{th} district in the four states North Dakota (MN), South Dakota (SD), Montana (MT) and Minnesota (MN) and subscript t is the time period. Equation 11 contains 18 district dummy variables to capture the differences in transportation costs to terminal locations or major demand points. Transportation cost is significant in wheat marketing as wheat must be moved to end-users demand locations. Transportation also adds spatial and temporal value to wheat where it is demanded. Two terminal market locations are identified in this study, Minneapolis, Minnesota and the Pacific Northwest Region. In this study, the Minneapolis market will be considered the principal market (Minnesota 1 is the default due to the proximity to this market). The Minneapolis market is where the Minneapolis Grain Exchange (MGEX) is located and where HRSW derivative products are traded. The Minneapolis market also has large storage capacities, a concentration of milling facilities, and major rail hubs. A local elevator will examine bids from various buyers located with influences from these major terminal facilities to find the entity that values the commodity the highest with transportation cost incorporated at a given time when a sale is desired. We anticipate negative signs for North Dakota and South Dakota districts with respect to the default market, Minneapolis market. Since Montana is closer to the PNW market, the sign of districts within Montana are ambiguous.

Quality characteristics variables in the data include protein, test weight, damaged kernels, and shrunken and broken kernels. The first three terms in the equation are the district protein average (protm), the interaction of district average protein and the average of all other districts within each state (ptod), and the interaction of district average protein with the annual protein level in the other states (ptos). A similar structure is in place for test weight (twtm, twtod, twtos). The next group of terms, shrunken and broken kernels (sbm, sbod) and damaged kernels (damm, damod) follow a similar pattern where sbod and damod represent the average of shrunken/broken and damaged kernels in all other districts within each state. The definitions of the variables are displayed in Table 3-1.

Protein for HRSW is expected to be related positively to price. Protein is an important component sought by wheat participant. Protein content is a predictor of how well the flour will bake (Stiegert & Blanc, 1997). In this study, an increase in the level of protein in other states' *X* district would be expected to decrease price in *X* district's state. Similarly, an increase in the level of protein in other districts' *X* district would be expected to decrease prices in *X* district.

Table 3-1: Definitions of Variables used in the Empirical Models

Variables	Definitions
$price_{it}$	District price deflated by HRSW marketing year prices($/bu.) in district i ($i = 1, 2, ..., 19$) and time period t ($t = 1, 2, ..., 15$)
$year_t$	Binary (0,1) term for each year
$district_i$	Binary (0,1) term for each district
$protm_{it}$	District protein (%/bu.)
$ptxptod_{it}$	**Interaction terms**: District protein * Production-weighted protein for all other districts in state (%/bu.)
$ptxptos_{it}$	**Interaction terms**: District protein * Production-weighted average for other state's annual average base protein (%/bu.)
$twtm_{it}$	District test weight (lbs./bu)
$twtxtwtod_{it}$	**Interaction terms**: District test weight * Production –weighted for test weight for all other districts in states (lbs./bu)
$twtxtwtos_{it}$	**Interaction terms**: District test weight * Production-average for other state's annual average base test weight (lbs./bu).
sbm_{it}	District Shrunken/broken kernels (%/bu.)
$sbxsbod_{it}$	**Interaction terms**: District shrunken/broken kernels * Production–weighted shrunken/broken kernels for all other district in state (%/bu.)
$damm_{it}$	District damage kernels ($/bu.)
$damxdamod_{it}$	**Interaction terms**: District damage kernels * Production-weighted of damage kernels for all other districts in state ($/bu.)

Test weight measures the density of wheat kernel (e.g., flour yield). A positive implicit value is expected. That is, a higher test weight means a high quality kernel which reduces milling cost and increases flour yield. In relation to this study, an increase in test weight in other states' *X* district would be expected to decrease price in *X* district's state. Similarly, an increase in the level of test weight in other districts' *X* district would be expected to decrease prices in district *X*. Damaged kernels and broken or shrunken kernels have a negative effect on prices. Thus, an increase in total defects in other districts' *X* district is anticipated to reduce prices in district *X*.

The estimation of marginal values for the various characteristics involves interaction terms which demonstrate the impact of characteristic supply levels between districts. The marginal value of protein is estimated as:

$$Equation\ (12) \qquad \frac{\partial Price_{i,t}}{\partial protm_{i,t}} = \beta_1 + \beta_2 ptxptod_{i,t} + \beta_3 ptxptos_{i,t}.$$

$ptxptod_{i,t}$ represents the level of protein in other districts' X district and $ptxptos_{i,t}$ represents the level of protein in other states' X district. The marginal value estimation procedure is repeated for the other quality characteristics in Equation 11. The estimation of the marginal value has more than one parameter which makes it difficult to determine the significance level. Because of that a standard t-statistics would be calculated using the marginal value over standard errors at each data point. The estimations are done for all the variables in Equation 11 above using Stata (2012), using the variance expression below to estimate the standard error for each marginal value.

$$Equation\ (13) \qquad var\left[\frac{dPrice_{i,t}}{dprotm_{i,t}}\right] = var(\beta_1) + {ptxptod_{i,t}}^2 * var(\beta_2) + {ptxptos_{i,t}}^2 * var(\beta_3) + 2 * ptxptod_{i,t} * cov(\beta_1, \beta_2) + 2 * ptxptos_{i,t} * cov(\beta_1, \beta_3) + 2 * \left(ptxptod_{i,t} * ptxptos_{i,t}\right) * cov(\beta_2, \beta_3)$$

CHAPTER 4

RESEARCH METHODS

Introduction

This chapter describes the data utilized in this study. The study investigates the effect of wheat characteristics and spatial quality levels for the Upper High Plains hard red spring wheat growing region over the period from 1998 to 2012. The sample period was chosen based on data availability. Data descriptions are examined including summary statistics. This chapter also discusses econometrics issues and tools for data analysis.

Data Description

Data for this study were comprised of hard red spring wheat daily prices and quality grading data on the four growing regions -North Dakota, South Dakota, Montana and Minnesota. Descriptive statistics of all the elements included in the model are presented in Table 4-1.

Price data from 1998 to 2012 was obtained from Cash Grain Bids for the four growing states. The dataset contained daily elevator cash prices across the HRS growing region for 13.5% HRSW. The data was grouped into state districts, (that is, Minnesota 4(MN4) - all elevators within MN4 and the other districts followed the same pattern). We then merged month (e.g. Aug) by year (i.e. 1998) to arrive at 'monthyear' categories (e.g. Aug1998) using the CONCATENATE command in Excel. Using the "average if" command in Excel, we derived the month-year values (e.g., AUG1998 = $2.92). These values were then converted into marketing year prices – July to June –and then deflated using HRSW marketing year prices from NASS to allow for "adjustment of exogenous supply and demand shocks which may have occurred overtime" by Espinosa &Goodwin (as cited in Parcell and Stiegert (1998, p.145)). But because the marketing year prices from NASS starts from 2002 through 2012, we manually calculated that of 1998 through 2001, using monthly marketing year prices from Quick Stats we found the averages for each year based on the trading period. All the other state districts followed similar data transformation.

Quality data for hard red spring wheat for the four growing regions were provided by annually published U.S. Wheat Crop Quality Report sponsored by U.S Wheat Associates in cooperation with the U.S Department of Agriculture's Foreign Agricultural Service. The report publishes various measures of wheat quality characteristics and physical attributes. The 2012 report shows that HRSW achieved a high grade and highly uniform kernel quality profile and functional performance with near zero damaged kernels. Protein levels were below normal and dough strength was generally weaker as compared with 2011. We also compared the wheat grading requirements in Table 1-2 to the quality dataset used in this study. The results show that 226 out of the 285 total observations were classified as U.S. No.1, while 58 were classified as U.S. No.2.

To measure the availability of each characteristic within the principal growing region for HRSW, a production-weighted average was calculated for each county to estimate the two interaction terms among the characteristics. Parcell and Stiegert (1998) use a similar approach, production weight adjustments to account for intra-regional availability of each characteristic. In this study, for example, the interaction term for shrunken and broken kernels in North Dakota district 1, was calculated as the production-weighted average of shrunken/broken kernels in North Dakota districts 2-9 multiplied by the average level of shrunken/broken kernels in North Dakota 1 district. Production data were collected from unpublished National Agricultural Statistics Service-Quick Stats. Similar procedures were followed for Minnesota, South Dakota and Montana.

Table 4-1: Summary Statistics of Selected Wheat Characteristics, 1998-2012

Characteristic	Obs[6].	Mean	Std. Dev.	Min	Max
Price ($/bu.)	284	8.59	1.04	7.57	11.69
Protein (%/bu.)	284	14.44	0.93	12.23	17.75
➢ Production-weighted	284	14.28	1.05	0	16.25
➢ State average protein	284	14.20	0.41	13.43	15.13
Test weight (lb/bu.)	284	60.19	1.62	54.98	64.17
➢ Production- weighted	284	60.21	3.78	0	62.84
➢ State average test weight	284	60.51	0.95	58.21	62.46
Shrunken/Broken (%/bu.)	284	1.29	0.71	0.27	4.47
➢ Production-weighted	284	1.26	0.47	0	2.96
Damage Kernels (%/bu.)	284	0.43	0.71	0	5.51
➢ Production-weighted	284	0.43	0.59	0	3.84

Econometric Issues

The data discussed above are used to estimate the marginal value of HRSW characteristics and spatial quality levels of wheat characteristics in the four growing regions. Because these characteristics differ across each state, there is a possibility of heteroscedasticity (different error variance for each characteristic). Also, the time series structure of the data possess the problem of autocorrelation, that is, the correlation between error term of HRSW price and each state region in different years.

[6] Missing observation was MN4 for 2008

The null hypothesis of homoscedasticity was tested against the alternative of group-wise heteroscedasticity using the Lagrange Multiplier test (Breusch-Pagan) for panel cross section time series data. The procedure of the test is as follows:

- Apply ordinary least squares (OLS) to obtain the residuals and squared it,
- Regress the squared residuals on the subset of the independent variables, and
- Under H_0 = homoscedasticity, the test statistic NR^2 is asymptotically distributed as chi-square χ^2 with J degree of freedom.

Using this procedure the calculated test statistics is 4.74 (with 18 degrees of freedom, 34.805) cannot reject the null hypothesis of homoscedasticity at 1% significance level for each characteristic in the four states.

For autocorrelation, the general test is Breusch-Godfrey test. But because the model in this study was estimated using panel cross sectional time series data, the test cannot be used directly. The appropriate test for this study is the modified vision of the Breusch-Godfrey test (Wu & Brorsen, 1995). The procedure of the test is as follows:

- Obtain the residuals $\hat{e}_{it}$ by applying OLS estimation to the model,
- Regress the residuals $\hat{e}_{it}$ on all independent variables to obtain the R-square such that, $\hat{e}_{it} = x_{it}\beta_1 + \gamma_{it}\hat{e}_{it-1} + e_{it}$, and
- Under H_0 =no autocorrelation, the test statistic, $(n-p)R^2$ is asymptotically distributed as chi-square with 14 degree of freedom, χ^2.

Using this procedure, the calculated test statistics is 3.86. The 1% critical value for the χ^2 distribution with 33 degrees of freedom is 20.7. Thus, the null hypothesis of no autocorrelation cannot be rejected. Also, because the price data was prices over time, a unit root test needed to be conducted. However, because of our small sample size a unit root test was not estimated.

In summary, due to the existence of cross sectional heteroscedasticity and time series autocorrelation in the dataset, we estimated Equation 11 using OLS estimator. We then adjusted the standard errors using the robust clusters for arbitrary forms of heteroscedasticity and autocorrelation. This command was used because the generalized estimator produces consistent standard errors if the residuals are correlated within but uncorrelated between groups of individuals. Although heteroscedasticity was undetected in this study, we assumed there may be some heteroscedasticity undetected, so we used the robust clusters method to correct for both errors.

CHAPTER 5

RESULTS AND DISCUSSION

Introduction

Chapter 5 presents and discusses the empirical results estimated using the econometric model presented in chapter 4 hedonic price model. This chapter looks at the inter-state and intra-state levels of wheat quality in determining the marginal price of wheat characteristics. Results are discussed in relation to the objectives of the study.

Marginal Values of HRS Wheat Characteristics

The hedonic price model developed in chapter four was used to estimate the implicit values of HRSW characteristics. Marginal implicit values are the changes in the price of a dollar per bushel of HRSW when there is a marginal change in the level of wheat characteristics. The change can either be a premium relative to a base bushel of HRSW (positive parameter) or discount relative to a base bushel of HRSW (negative parameter) as shown in the results.

Econometric estimates of Equation 11 are reported in Table 5-1. The model explained 98% of the variation in hard red spring wheat prices. Most coefficients were significantly different from zero at 1%, 5% and 10% levels and were of the expected directional signs, but this study focuses on the significance of marginal values (Table 5-2) and not the individual parameter estimates from the OLS regression (Table 5-1). Positive parameter estimates indicate a premium relative to a base bushel of HRSW and negative parameter estimates indicate a discount relative to a base bushel of HRSW. Table 5-1 reports OLS regression coefficient of each of the quality characteristics, the standard errors, and the standard t-statistics as shown below.

The results showed that protein and test weight were significant at the district and state levels (OD and OS variable) at 1% and 5% level, respectively, and were of the expected directional signs, according to economics theory and previous literature. These findings are consistent with previous studies. A percentage increase in protein is associated with an increase of $0.4356/bushel in HRSW prices, while a pound increase in test weight is associated with $0.1675/bushel increase in HRSW prices. This is an indication that buyers believed protein followed by test weight is the most important grade characteristics because it receives the largest premiums/discounts in the districts and between state levels. Damaged kernels and shrunken and broken kernels were statistically insignificant, that is, damaged kernel and shrunken and broken kernels information had no marginal effect on HRSW prices in both the district and other districts within a state. These results were expected since the other two characteristics shrunken/broken kernels and damaged kernel merely further describe HRSW characteristics across the district.

Table 5-1: Regression Estimates of HRSW Quality Characteristics, 1998-2012

Parameter	Coefficient	Std. Error	t-statistic
Intercept	7.9590	0.8515	9.35***
Protein	0.4356	0.1536	2.84***
ptxptod	-0.0020	0.0024	-0.80
ptxptos	-0.0275	0.0095	-2.90***
Test Weight	0.1675	0.1003	1.67*
twtxtwtod	0.0001	0.0001	0.95
twtxtwtos	-0.0029	0.0016	-1.76*
Damaged	0.0385	0.0661	0.58
damxdamod	-0.0404	0.0440	-0.92
Shrunken/broken	0.0576	0.0364	1.58
sbxsbod	-0.0224	0.0193	-1.16
District & Yearly Dummy Variables			
Minnesota 4	0.0574	0. 0128	4.47***
Montana 2	0. 5018	0. 0363	13.82***
Montana 3	-0. 0433	0. 0232	-1.87*
Montana 5	0.5554	0.0392	14.16***
Montana 10	0.4318	0.0532	8.11***
North Dakota 1	-0.5015	0.0523	-9.58 ***
North Dakota 2	-0.4308	0.0472	-9.11***
North Dakota 3	-0.2430	0.0446	-5.45***
North Dakota 4	-0.4726	0.0502	-9.40***
North Dakota 5	-0.2880	0.0452	-6.36***
North Dakota 6	-0.2260	0.0432	-5.23**
North Dakota 7	-0.3668	0.0588	-6.23***
North Dakota 8	-0.4272	0.0501	-8.53***
North Dakota 9	-0.1174	0.0424	-2.77***
South Dakota 1	-0.2959	0.0404	-7.32***
South Dakota 2	-0.0286	0.0217	-1.32
South Dakota 3	0.1081	0.0204	5.29***
South Dakota 5	-0.0138	0.0199	-0.69
Year1999	-0.2422	0.1247	-1.94*

Year2000	-0.0180	0.0802	-0.23
Year2001	0.1142	0.0660	1.73*
Year2002	0.1816	0.0659	2.76***
Year2003	0.1956	0.1443	1.36
Year2004	0.0451	0.1029	0.44
Year2005	0.5885	0.0637	9.24***
Year2006	0.5975	0.1018	5.87***
Year2007	3.6664	0.1451	25.27***
Year2008	-0.0546	0.2169	- 0.25
Year2009	0.1233	0.1995	0.62
Year2010	2.4135	0.1554	15.53***
Year2011	0.1342	0.1058	1.27
Year2012	0.2714	0.1461	1.86 *

Note:

- Model R-square = 0.98
- ***, **,* denote coefficients significantly different from zero at 1%, 5%, 10% levels respectively
- For the district dummy variables, Minnesota 1 is assigned as the base.

An estimation of marginal values for the various quality characteristics using Equation 12 and standard t-statistic using Equation 13 are display in Table 5-2 below.

Table 5-2: Marginal Value of HRS Wheat Characteristics, 1998-2012

Characteristics	Marginal Value ($/bu.)	Std. Dev.	t - Statistics
Protein:			
District	0. 3446	0.0818	4.22***
Other districts' *X* district	-0.0020	0.0019	-1.05
Other States' *X* district	-0. 0275	0. 0081	- 3.38***
Significant data point[7]	99%		
90% confidence interval [8]	[0.209 - 0.479]		
Test Weight:			
District	0.1316	0.0530	2.48**
Other districts' X district	0.0001	0.0001	1.18
Other States' X district	-0.0029	0.0011	-2.67***
Significant data point	95%		
Shrunken/Broken Kernels:			
District	0.0848	0.1825	0.48
Other districts' X district	-0.0403	0.0513	-0.79
Significant data point	0%		
Damaged Kernels:			
District	-0.5544	0.1489	-3.78***
Other districts' X district	-0.0224	0.0186	-1.20
Significant data point	0%		
District & Yearly Dummy Variables			
Minnesota 4	0.0578	0.0627	0.92
Montana 2	0.5019	0.0739	6.79***
Montana 3	-0.0434	0.0678	-0.64
Montana 5	0.5554	0.0714	7.78***

Significant data points are the percentage of data points that are statistically significant and of the expected sign.

[8] Confidence intervals was calculated using $marginal\ \text{Value} \pm 1.64 * Se$

Montana 10	0.4318	0.0962	4.49***
North Dakota 1	-0.5016	0.0720	-6.96***
North Dakota 2	-0.4308	0.0706	-6.10***
North Dakota 3	-0.2430	0.0722	-3.36***
North Dakota 4	-0.4727	0.0719	-6.57***
North Dakota 5	-0.2881	0.0703	-4.10***
North Dakota 6	-0.2260	0.0698	-3.24***
North Dakota 7	-0.3668	0.0731	-5.02***
North Dakota 8	-0.4273	0.0727	-5.88***
North Dakota 9	-0.1175	0.0699	-1.68*
South Dakota 1	-0.2959	0. 0698	-4.24***
South Dakota 2	-0.0287	0.0640	-0.45
South Dakota 3	0.1081	0.0641	1.69*
South Dakota 5	-0.0138	0.0658	-0.21
Year1999	-0.2422	0.1169	-2.07**
Year2000	-0.0181	0.0945	0.19
Year2001	0.1142	0.0804	1.42
Year2002	0.1816	0.0761	2.39**
Year2003	0.1956	0.1294	1.51
Year2004	0.0451	0.1325	0.34
Year2005	0.5885	0.0695	8.47***
Year2006	0.5975	0.0855	6.99***
Year2007	3.6664	0.1089	33.65***
Year2008	-0.0546	0.1449	-0.38
Year2009	0.1233	0.1938	0.64
Year2010	2.4135	0.1450	16.64***
Year2011	0.1342	0.0824	1.63
Year2012	0.2714	0.1047	2.59***

Note:

- Model R-square = 0.98
- ***, **,* denote coefficients significantly different from zero at 1%, 5%, 10% levels respectively
- For the district dummy variables, Minnesota 1 is assigned as the base.

The estimated coefficients for the district dummy variables reflect premiums and discounts relative to the district not included. Because the district not included is closest to the principal terminal market, (that is, Minnesota 1 is closest to Minneapolis for HRSW), the parameter estimates are approximations of transportation costs from each district. As shown in Table 5-2, those districts farthest from the base price location received large discounts/premiums. South Dakota had discounts from $0.0138 to $0.1081/bushel and North Dakota had discounts from $0.1175 to $0.5016/bushel. North Dakota and South Dakota are compared to the default market which is closer to the Minnesota terminal market. North Dakota and South Dakota are further away than the default from Minneapolis, so we expect higher transportation costs, i.e., negative coefficients as compared to the default. For Montana, we were unable to hypothesize the signs of the regions because of the two terminal markets availability. In general, the district dummy values seem to suggest the spatial price relationship as a result of transportation and handling charges.

On the other hand, the yearly dummy variable was added to the model to control for spontaneous increases and decreases in prices over this time span. The data indicated that there was a large increase in price between 2007 and 2010 and a large decrease between 2008 and 2011, but no corresponding increase or decrease in HRSW characteristics occurred. Therefore, the yearly dummy variables were added to control for prices. Their estimated coefficients were statistically significant at 1%, 5% and 10%.

In Table 5-2 above, each marginal value for protein and test weight were calculated using Equation (12) and the standard errors were calculated using Equation (13). Almost all observations for protein, (99%) were significantly different from zero at the 10% level and of the expected positive sign. The mean and standard deviation of protein marginal values were $0.2917/bushel and $0.1356 /bushel, respectively. Using this information in calculating the normal confidence interval – provides a statistical method for deriving a range in which an unknown population parameter will likely fall. It is also based on sample size or data-, a 90% confidence interval was estimated to be between $0.209 and $0.479 /bushel. This study shows that the marginal value of protein had increased as compared to Parcell and Stiegert's (1996) estimates. Specifically, Parcell and Stiegert found the mean and standard deviation of DNSW were $0.060/bushel and $0.0045/bushel, respectively. Although this study indicates a higher marginal value of protein, it also shows a wider confidence interval for the marginal value of protein as compared to Parcell and Stiegert's estimates which are based on a smaller sample size. Parcell and Stiegert estimated a confidence interval between $0.046 /bushel and $0.074 /bushel for DNSW. The wider confidence interval, greater variability around the point estimate, found in this this study indicates a greater uncertainty of premium values for protein. One important implication is that wheat producers' varietal choice decisions depends on the yields and price volatility at the time of planting as well as wheat characteristics. Wheat producers have to make important decisions about the varieties they will plant, the quality characteristics of the type; at the same time are concerned with maximizing profitability of their operations while trying to mitigate financial risk. There are other types of risk that wheat producer's faces every day, production risk, price/market risk, financial risk, institutional risk and human or personal risk. With these types of risk, farmers cannot protect themselves against (systematic risk) but with financial risk (unsystematic risk) farmers can protect themselves against by minimizing their exposure. If protein premiums are volatile, then producers may be hesitant to adopt wheat varieties that have the probability of resulting in higher end-quality characteristics levels than yield benefits. Producers' adoption of wheat varieties that exhibit this type of tradeoff will depend on their risk tolerance.

The estimated parameters for protein were positively related to district prices, ceteris paribus; hence, if protein goes up by 1%, the marginal value of a bushel goes up by 34 cents. Because HRSW prices were negatively related to other states' *X* district protein, when the level of protein in other states' *X* district increased, the marginal value of a bushel of HRSW would decline by 2.28 cents *X* district's state, indicating the presence of spatial competition in HRSW quality characteristics. Also, the coefficient for other district's *X* district signifies that if protein in HRSW increases, it would not have any effect on *X* district prices because the coefficient is not significant. Figure 5-1 shows the plot of estimated average marginal values of protein for the four growing states. The graph shows how highly varied the levels of protein and the effect of this in determining the value of protein in the four growing states. The graph also shows the change in the average district's marginal value of HRS wheat protein from a change in both the level of protein in other districts' *X* district and from a change in the level of protein in the other states' *X* district.

For test weight, 95% of its marginal values at each data point were significant at 10% level and of the expected positive sign. The estimated parameters were positively related to district prices; thus, as test weight went up by a pound, the marginal value of a bushel went up by 13.2 cents, but responded negatively to other states' *X* district. Hence, as the test weight in other states' *X* district increased, the marginal value of a bushel of

HRSW declined by 0.29 cents in *X* district's state, indicating the presence of spatial competition in HRSW quality characteristics. Figure 5-2 shows the average marginal values of HRSW test weight. However, the variability was minimal with a range of \$0.088/bushel to \$0.96/bushel.

These results are consistent with Parcell and Stiegert's paper "Competition for U.S. Hard Wheat Characteristics." Parcell and Stiegert (1998) found a relatively strong positive relationship between own district protein (test weight) and price for North Dakota Dark Northern Spring (DNS), which is a sub-type of hard red spring wheat (HRSW). All observations for North Dakota DNS wheat were significantly different from zero at 10% level and were of the expected positive sign. The mean and standard deviation of protein marginal values were \$0.060 /bushel and \$0.0045 bushel, respectively. Estimated confidence intervals were \$0.046 to \$0.074/bushel using Chebychev's inequality. This was a more narrow confidence internal than what this study found using the standard confidence interval. Parcell and Stiegert also found that the marginal values of protein in North Dakota DNS were affected by the level of protein in the other regions. Additionally, test weight was significant at each data point.

Aside from protein and test weight, two additional grading characteristics were analyzed in our hedonic model: shrunken and broken kernels and damaged kernels. For damaged kernels, none of the marginal values were statistically significant. Additionally, none of the marginal values for shrunken and broken kernels were statistically significant, which is in alignment with our hedonic model expectation.

The comparison is based on the value estimating procedure established by Parcell and Stiegert (1998). For Parcell and Stiegert the marginal value of DNS damaged kernels were statistically insignificant, which was the same finding as this study. Also, Parcell and Stiegert showed that DNS discounts for shrunken/broken kernels were unaffected by the quality of wheat in other locations. However, in this study is was shown that shrunken and broken kernels in other districts would result in discounts for a district, while a district's own level of shrunken and broken kernels was not found to have a significant marginal value. Shrunken and broken kernels area factor that could affect processing costs and flour yield. Overall, these results were expected because damaged kernels and shrunken/broken kernels are controlled at the terminal elevators or county level (removed in the pre-milling stages) through cleaning and screening. But sometimes fewer damaged kernels may indicate a crop with uniform kernel quality, which is a highly desirable trait in domestic milling and in the export market (Stephens, 1997).

It was investigated whether inflation could be a factor influencing marginal wheat characteristic values over time. This was accomplished by adjusting the price data with CPI data and re-running the regression models. The results showed a slight difference in values; however, they were not significantly different from the previous described results. For a detailed explanation on this aspect of the results, see appendix C. This provides us with further support in comparing this study's wheat characteristic values to Parcell and Stiegert's study, with no indication that inflation contributes in a significant way to wheat characteristic valuations.

Studies of the international wheat market also found protein and test weight to be important characteristics in export markets. Dahl and Wilson (1998) found that variability in quality characteristics reduces from the farm-level to export level. For instance, protein and dockage showed a reduction in variability from farm level to export level. Uri et al. (1994) also found that protein premium for HRSW was $14.14/MT ($0.3848/bushel) and test weights were $0.20/bushel for DNS. They also found that kernel density was significantly high. Wilson (1989) identified a small but increasing premium for hard wheat of $2.0/ton ($0.0544/bushel) in the mid-1970s and $3.00/ton ($0.0816/ bushel) in the mid-1980s.

Figure 5-1: Marginal Value of HRS Wheat Protein, 1998-2012

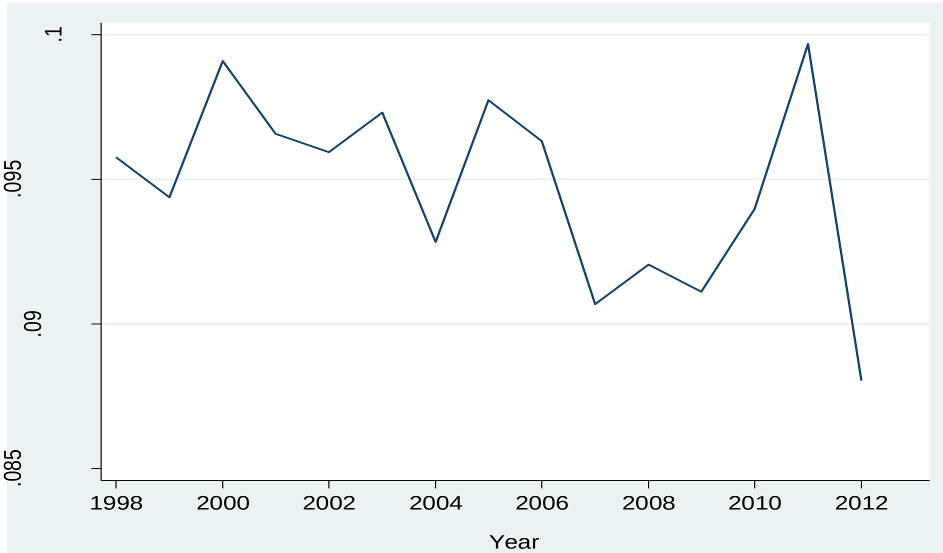


Figure 5-2: Marginal Value of HRS Wheat Test Weight, 1998-2012

The two figures below shows the marginal value of protein and protein level as well as the marginal value of test weight and test weight level. In both Figure 5-3 and Figure 5-4 there are some outliers but specifically all protein and test weight levels were within the space of their marginal values.

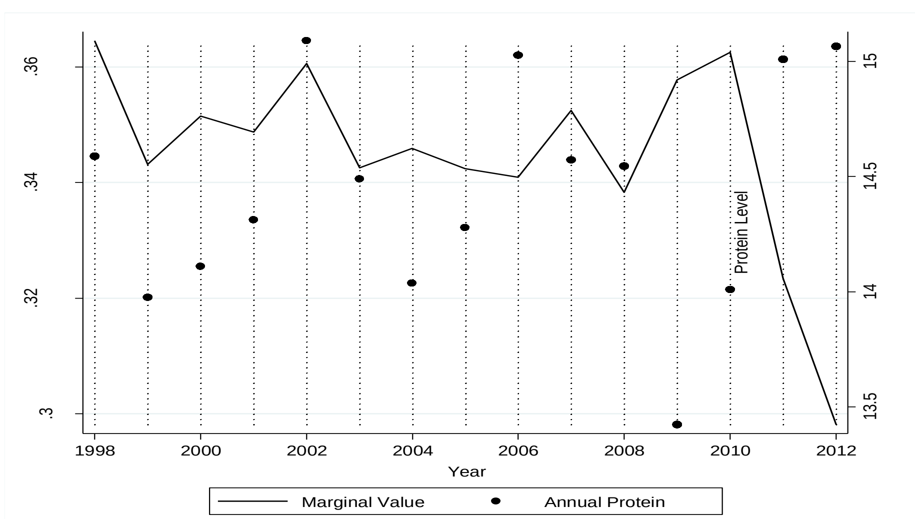


Figure 5-3: Marginal Value of Protein and Protein Level, 1998-2012

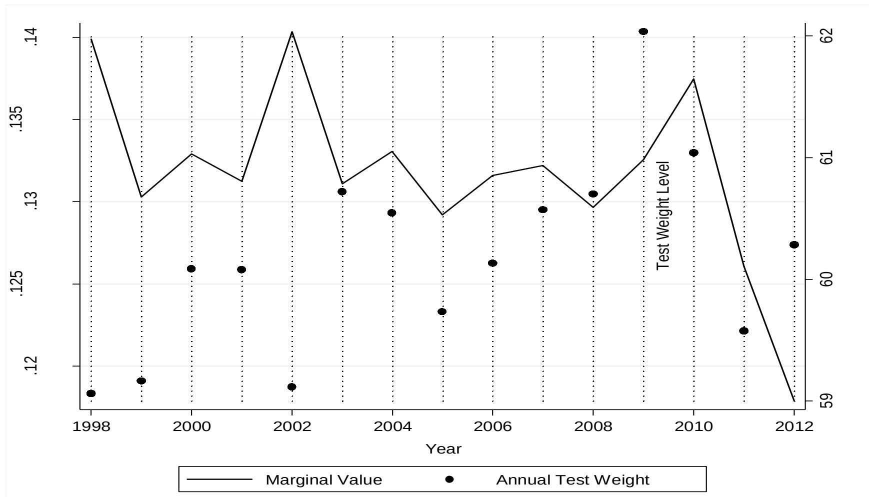


Figure 5-4: Marginal Value of Test Weight and Test Weight Level, 1998-2012

CHAPTER 6

CONCLUSIONS

This study investigates the influence of wheat characteristics and spatial quality levels for the Upper High Plains hard red spring wheat growing region using the hedonic price model. Model parameters were estimated with Panel cross sectional time series data comprised of cash prices of hard red spring wheat from cash grain bids, quality data from U.S. Wheat Crop Quality Report and production data from unpublished NASS Quick Stats. The cash price of HRSW was then transformed to marketing year price (July to June) based on HRSW.

Also, considering that premium or discount prices for specific quality characteristics might be affected by the production-weighted values of the same characteristics in other districts' *X* district or same characteristics in other states' *X* district. Interaction variables were developed within the state (intra-state) and then between states (inter-state) to capture changes in the marginal value of each characteristics as the supply of those characteristics changes within and between the growing districts/states. The interaction term for protein and test weight were evaluated in intra-state and inter-state framework. Shrunken and broken kernels, as well as damaged kernels, were evaluated on an intra-state basis. These were achieved by following the work of Ladd and Martin's (1976) hedonic price model which gives the marginal implicit value for each characteristic. The study attempted to estimate the implicit value of wheat quality characteristics and the spatial quality levels of wheat characteristics for hard red spring wheat growing states. Thus, we examined price difference associated with wheat quality characteristics in the four growing states.

Hard Red Spring wheat quality characteristics are becoming more important as markets realize its impact in relation to utility. That is, there is a high demand as it is usually mixed with other low protein content wheat to make by- products. Also, because differences in quality levels exist, quantifying the impacts of these quality price differences is essential so that wheat participants understand the implicit value of enhancing trait levels within the marketing supply chain.

Our empirical results paper using the hedonic model confirmed the conclusion derived by Parcell and Stiegert paper on dark northern spring (DNS) wheat that the marginal values of protein were affected by the level of protein in other districts within a state and between states. The results also suggest that premiums for test weight, discounts for shrunken/broken kernels and damaged kernels were not affected by wheat quality in other districts' *X* district. Also, results on the district dummy variables showed that most of the time districts farthest from the principal market receive large discounts because of high transportation costs associated with moving grain. These findings illustrate that protein and test weight are affected by quality characteristics in other states' *X* district, while there were no intra-state effects found. Shrunken/broken kernels showed an intra-state effect on prices, while no intra-state effect for damaged kernels was found.

The estimated coefficients for district dummy variables were used to control for regional differences, including transportation costs effect on wheat prices (see chapter 4 and 5). The findings clearly suggest that regional differences play an important role in wheat marketing aside from the characteristics of wheat. Also, flour milling is an important factor in wheat production since the major end-use of wheat is flour. Results also showed that the higher the quality of wheat produced, the higher the quality of flour yield since the by-product of wheat is flour. Although this study indicates a higher marginal value of protein, it also shows a wider confidence interval for the marginal value of protein as compared to Parcell and Stiegert's estimates. The wider confidence interval found in this study indicates a greater uncertainty of premium values for protein. One important implication is that wheat producers' varietal choice decisions depends on the yields and price volatility at the time of planting as well as wheat characteristics. Wheat producers have to make important decisions about the varieties they will plant, the quality characteristics of the type; at the same time are concerned with maximizing profitability of their operations while trying to mitigate risk, especially financial risk. If protein premiums are volatile, and uncertain, then producers may be hesitant to adopt wheat varieties that have the probability of resulting in higher end-quality characteristics levels than yield benefits. Producers' adoption of wheat varieties that exhibit this type of tradeoff will depend on their risk tolerance and type of price signals sent. Wheat breeders make decisions that have tradeoffs between quality and yield; they must balance profitability for producers and millers. This research shows the importance of spatial competition on wheat prices. Wheat breeders that develop varieties that enhance characteristics levels that are widely adopted across state lines that improve the average characteristic levels of that area could decrease the marginal value of that characteristic. However, if wheat breeders develop varieties that are adopted more on a local, state level, there should be no impact on the marginal value on the associated characteristic.

This research provides transparency of the valuation of wheat characteristics for all individuals along the supply chain, including producers to end-users. This information can be utilized by these individuals along the supply chain to enhance profitability.

Farmers having knowledge about the marginal values of these characteristics, and changes in marginal values, provide insight on which characteristics wheat buyers' value most and the variability of characteristic premiums. This research demonstrates the tradeoffs and risks that producers face with respect to wheat varietal selection decisions. Producers could explore hedging opportunities to manage price risk. End-users that place a higher valuation on quality characteristics, could consider offering incentive mechanisms to producers that offset their risk associated to certain variety selections. Furthermore, end users can pursue integration to reduce competition when quality wheat is in short supply or segregation and time transportation is costly. Challenges exist to achieve desired quality wheat attributes through breeding and management along with reducing environmental factors influence on determining characteristic levels. Challenges also exist in segregating and transporting quality wheat during specific time periods.

More research needs to focus on investigating the effectiveness of the grading system by examining willingness to pay for characteristics of hard red spring wheat. Research should also examine more holistic approaches to maximizing the value in the wheat supply chain that incorporates breeding, management, and environmental factors.

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Appendix A

State District Maps

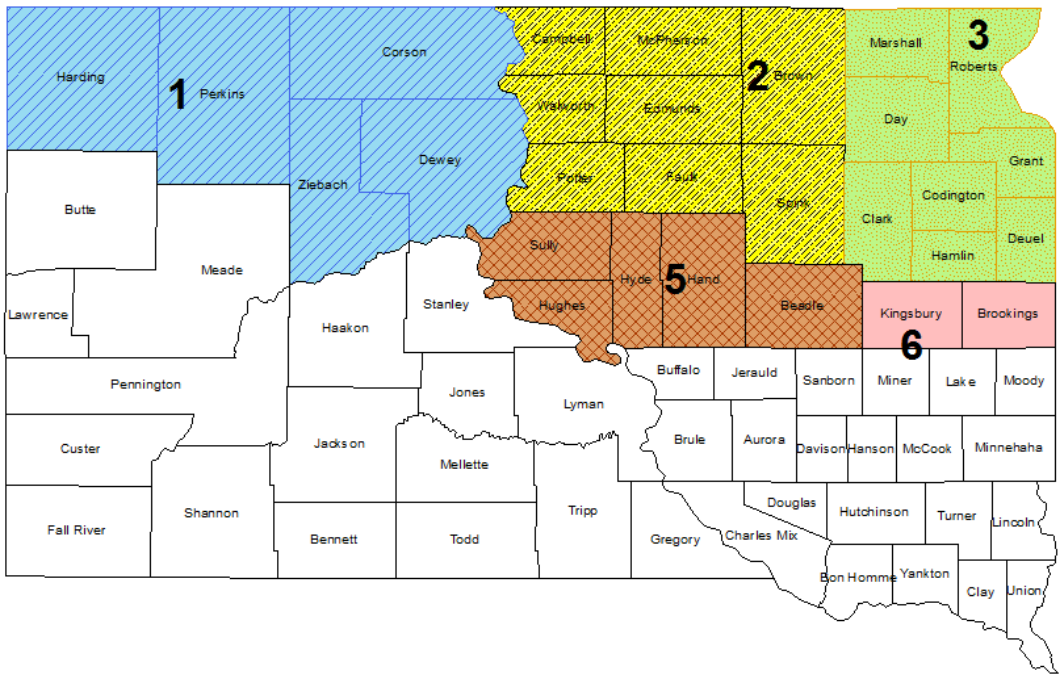


Figure A-1: South Dakota Districts

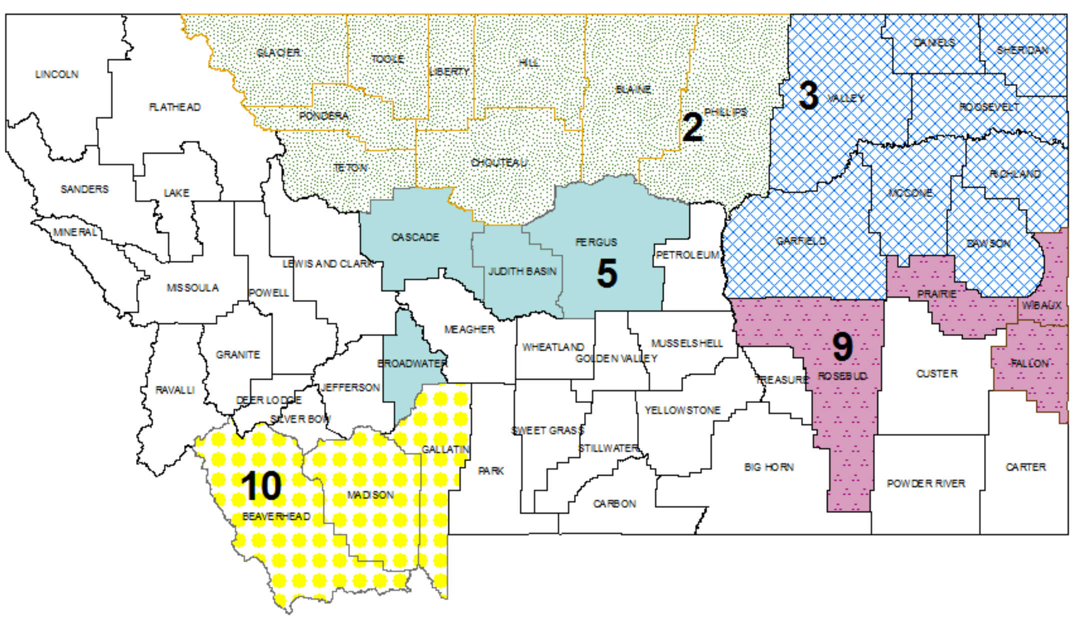


Figure A-2: Montana Districts

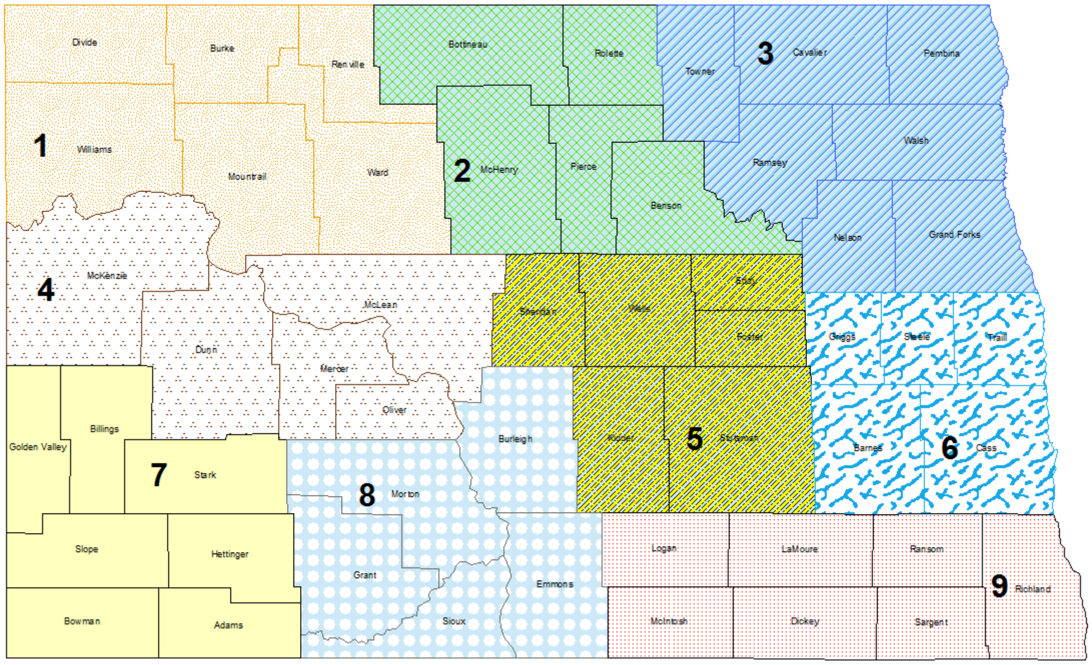


Figure A-3: North Dakota Districts

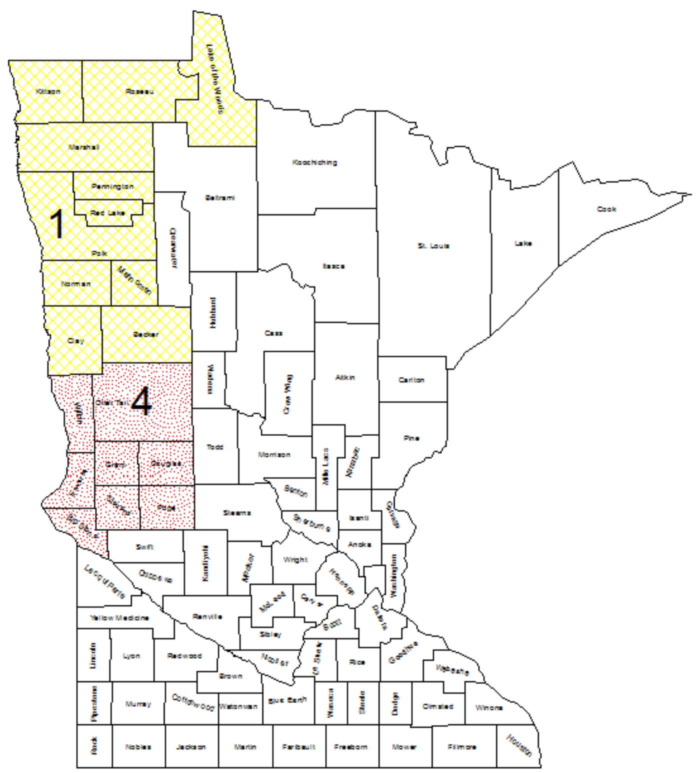


Figure A-4: Minnesota Districts

Appendix B

Further Background Information

Global Wheat Production

Wheat is a commodity that is produced across the world. Over the past ten years, European Union (EU), China, India, United States and Russia have been the five largest wheat producing countries in the world. Other major producing countries are Canada, Australia, Pakistan, Ukraine and Turkey. Because of differences in soil types and climates, wheat produced in one country generally differs from that produced in other countries in terms of quality. The 10 countries produce on average 83% of the world's total wheat (Foreign Agricultural Service, 2004-2013).

Table A-1: World Wheat Production 2010-2014 (1000 metric tons)

Country	2010	2011	2012	2013	2014	Average	Share
Argentina							
Common	17,200	15,500	9,300	10,500	12,500	13,000	1.9
Australia							
Common	27,410	29,905	22,856	26,929	24,000	26,220	3.8
Canada							
All	23,300	25,288	27,205	37,530	29,300	28,525	4.1
EU							
All	136,667	138,182	133,949	143,513	155,685	141,599	20.6
United States							
All	58868	54244	61298	58105	55129	57,529	8.4
Others Producers All	386,114	432,654	403,933	439,520	448,145	422,073	61
Total World							
All	649,559	695,773	658,541	716,097	724,759	688,946	100

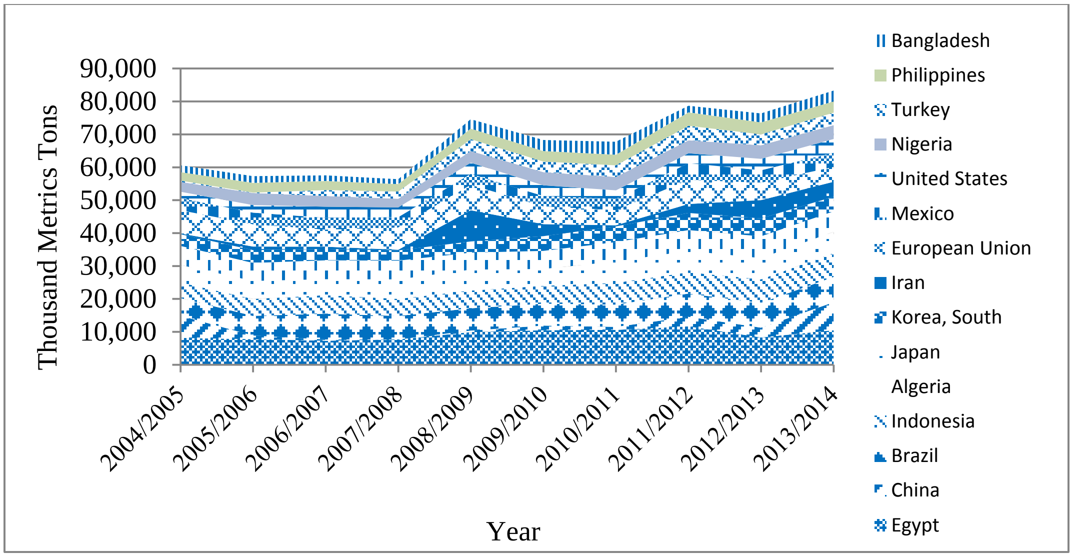
Source: Foreign Agricultural Service, Official USDA

In Table A-1, Argentina produces wheat that has characteristics of both soft and hard wheat with an annual average of 13.0 million metric tons between 2010 and 2014. Australia produces soft winter and semi-hard spring wheat with an annual average production of 26.2 million metric tons between 2010 and 2014. In the European Union (EU), annual average production was 141.6 million metric tons between 2010 and 2014, while Canada's production was 28.5 million metric tons. The United States average production for 2010 through 2014 was 57.5 million metric tons.

Global Wheat Trade

World wheat trade comprised of exports and imports from the world perspective. This section examines the world's top wheat importers and exporters.

The world's major wheat importing counties for 2004 to 2013 includes Egypt as the number one wheat importing country followed by China, Brazil, Indonesia, Algeria, Japan, South Korea, Iran, European Union, Mexico, United States, Nigeria, Philippines, and Bangladesh (Figure A-5). The United States and EU, major exporters of wheat, now import significant amounts of wheat from Canada, Argentina and Australia.



Source: Foreign Agricultural Service (2004-2013)

Figure A-5: Current Top 12 Wheat Importing Countries, 2004/05-2013/14

For exports, the six major exporting countries in the world are the United States, European Union, Canada, Australia, Russia and Ukraine. Other major exporting countries are Kazakhstan, India, Argentina and Turkey. These countries account for 91.9% of world wheat exports. In Table A-2, the United States, exports on average 29.6 million metric tons from 2010 to 2014, followed by the EU with an average of 25.2 million metric tons from 2010 to 2014. Canada exports HRSW and Durum to China and East Asia but currently the United States and EU are in competition with them for market share in those markets (Taylor & Koo, 2013).

Table A-2: World Wheat Export, 2010 - 2014 (1000 metric tons)

Country/Class	2010	2011	2012	2013	2014	Average	Share
Argentina							
Common	9,495	12,926	3,550	2,200	6,500	6,934	4.6
Australia							
Common	18,600	24,661	18,657	18,621	17,000	19,508	12.9
Canada							
All	16,575	17,352	18,970	23,238	23,000	19,827	13.1
EU							
All	23,086	16,728	22,677	31,925	31,500	25,183	16.7
United States							
All	35,147	28,608	27,544	32,012	24,494	29,561	19.6
Others Producers All	29,900	57,976	45,963	57,778	58,075	49.938	33.1
Total World							
All	132,803	158,251	137,361	165,774	160,569	150,952	100.

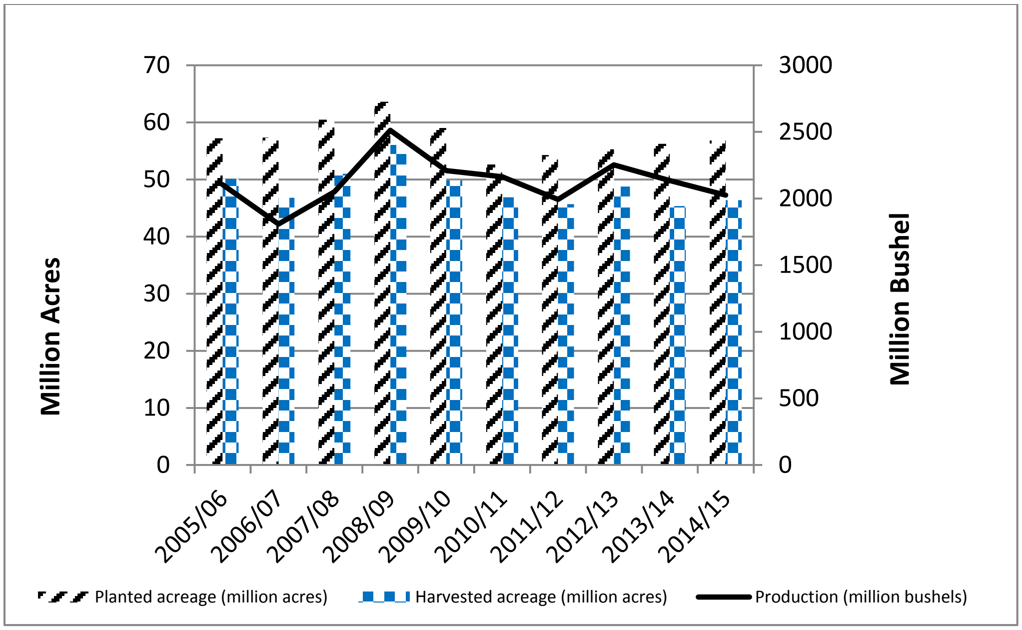
Source: Foreign Agricultural Service, Official USDA

U.S. Wheat Industry

U.S. Wheat Trade

United States wheat production and exports have long been dominated by hard red winter wheat. This section discusses production, exports and imports of U.S wheat during the 2004 to 2013 marketing year (a twelve month period during which a crop is normally marketed, thus, marketing year for HRSW is July-June).

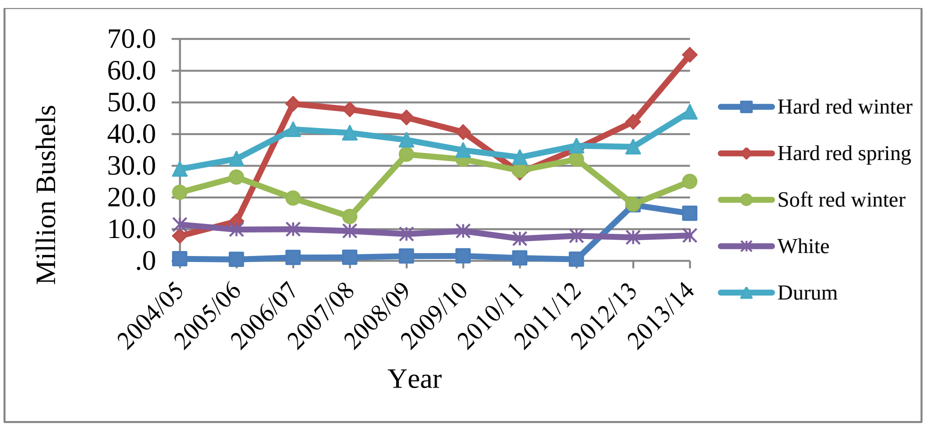
Figure A-6 displays all wheat production, planted acreage, and harvested acreage in the United States for the period between 2005/06 and 2014/15. Figure A-6 suggests that wheat production has fluctuated by around 2 billion bushels between 2005 and 2014. In 2008/09 there was a large increase in planted acres leading to a large increase in production.



Source: (National Agricultural Statistics Service, 2005-2014)

Figure A-6: U.S. Wheat Planting and Production (Acres/Bushels)

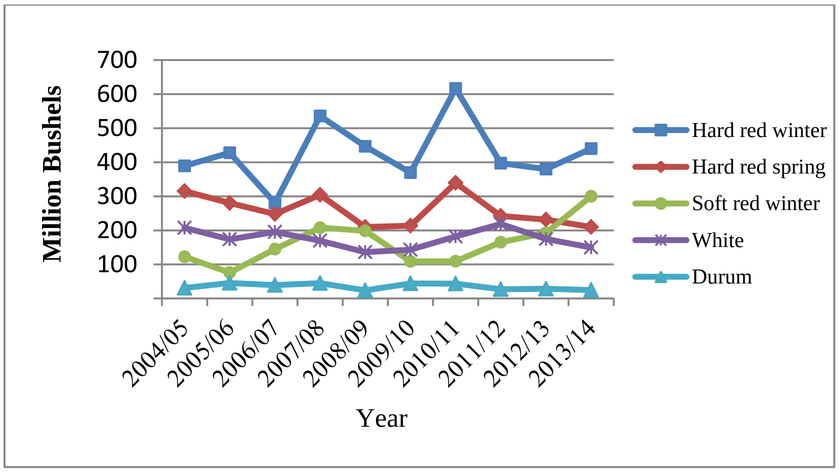
For imports, Figure A-7 shows that the United States only imports low quantities of wheat from other countries. In 2004 to 2013, the largest imports of wheat were HRSW (33.4%), followed by Durum (32.8%) and SRW (22.3%). Imports were the highest in 2008; however, they decreased after that year to levels more typical over this time span.



Source: USDA/ERS (2004-2013) and Production (1953)

Figure A-7: U.S. Import by Class, 2004/05-2013/14

The United States has typically been the world's largest wheat exporter. Figure A-8 shows that the largest wheat class exported is HRW, which experienced an increase in 2007 and 2008 as a result of large stocks and deprecation of the U.S. dollar (the depreciation of the dollar against other currencies makes it more attractive for other countries to import from the US) by about 25% against other currencies. The next largest wheat type exported is HRSW followed by white wheat, SRW, and durum (Wheat Outlook, 2013).



Source: USDA/ERS (2004-2013) and Production (1953)

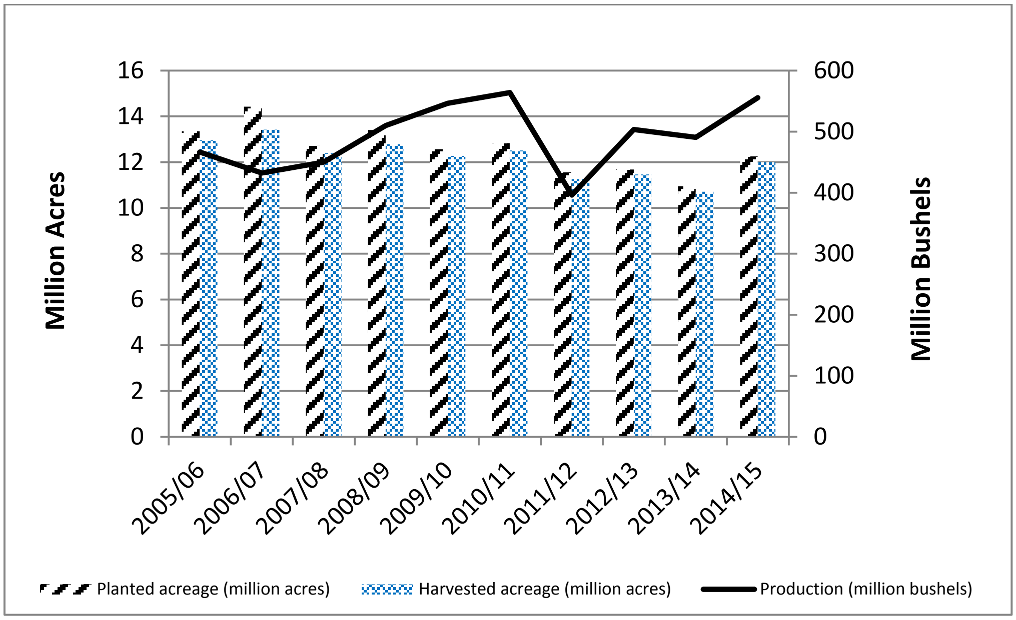
Figure A-8: U.S. Export by Class, 2004/05 to 2013/14

Hard Red Spring Wheat

U.S Hard Red Spring Wheat Trade

This section explains HRS wheat planting and production from 2005 through 2014 as displayed in Figure A-9. As shown in Figure A-9, production experienced a large increased from 2006 to 2010 and a large decrease in 2011 with it bouncing back in 2012.

In 2014, production was close to the high in 2010. (database from National Agricultural Statistics Service (2005-2014).



Source: Database from National Agricultural Statistics Service (2005-2014)

Figure A-9: U.S. HRS Wheat Planting and Production (Acres/Bushels)

In conclusion, wheat is an essential commodity in the manufacturing of many by-products. The five countries - European Union, China, India, United States and Russia produced 66.7% of total production in the period tracked (Foreign Agricultural Service, 2004-2013). Exports are dominated by a limited number of countries- the United States, European Union, Canada, Australia, and Russia.

Appendix C

Additional Information on Results and Analysis

This section of the results test whether inflation could be a factor influencing marginal wheat characteristic values overtime. This was accomplished by adjusting the price data with CPI data and re-running the regression models. This was achieved by first setting 1998 as the base year and then dividing through the yearly values by the base year to obtain the CPI. Afterwards, the original price values were divided by the price index (created using the HRSW marketing year prices) and then multiplied by the CPI created. Using the adjusted prices, the regression models were ran and the results are discussed in relation to the objectives of the study.

Econometric estimates of Equation 11 are reported in Table A-3. The model explained 99% of the variation in hard red spring wheat prices. Most coefficients were significantly different from zero at 1%, 5% and 10% levels and were of the expected directional signs. Positive parameter estimates indicate a premium relative to a base bushel of HRSW and negative parameter estimates indicate a discount relative to a base bushel of HRSW. Table A-3 reports OLS regression coefficient of each of the quality characteristics, the standard errors, and the standard t-statistics as shown below.

The results showed that protein was significant at the district and state levels at 1% and were of the expected directional signs, according to economics theory and previous literature. Thus, a percentage increase in protein is associated with an increase of $0.4259/bushel in HRSW prices. Test weight was statistically insignificant at the district and state levels, that is, it has no marginal effect on HRSW prices. Damaged kernels and shrunken and broken kernels were statistically insignificant, that is, damaged kernel and shrunken and broken kernels values had no marginal effect on HRSW prices in both the district and other districts' *X* district. These results were expected since the other two characteristics shrunken/broken kernels and damaged kernel merely further describe HRSW characteristics across the district.

Table A-3: Regression Estimates of HRSW Quality Characteristics, 1998-2012

Parameter	Coefficient	Std. Error	t-statistic
Intercept	7.7207	0.9902	7.80***
Protein	0.4259	0.1608	2.65***
ptxptod	-0.0023	0.0027	-0.83
ptxptos	-0.0266	0.0101	-2.64***
Test Weight	0.1472	0.1262	1.17
twtxtwtod	0.0001	0.0001	0.98
twtxtwtos	-0.0025	0.0021	-1.20
Damaged	0.0560	0.0674	0.83
damxdamod	-0.0487	0.0436	-1.11
Shrunken/broken	0.0781	0.0426	1.83*
sbxsbod	-0.0310	0.0215	-1.45
District & Yearly Dummy Variables			
Minnesota 4	0.0715	0.0139	5.16***
Montana 2	0.6598	0.0440	14.99***
Montana 3	-0.0242	0. 0275	-0.88
Montana 5	0.6882	0.0460	14.97***
Montana 10	0.6088	0.0642	9.48***
North Dakota 1	-0.5327	0.0569	-9.37***
North Dakota 2	-0.4510	0.0518	-8.70***
North Dakota 3	-0.2502	0.0495	-5.06***
North Dakota 4	-0.4908	0.0545	-9.01***

North Dakota 5	-0.2885	0.0489	-5.90***
North Dakota 6	-0.2302	0.0474	-4.86***
North Dakota 7	-0.3605	0.0644	-5.60***
North Dakota 8	-0.4428	0.0551	-8.03***
North Dakota 9	-0.1011	0.0463	-2.18**
South Dakota 1	-0.3210	0.0479	-6.70***
South Dakota 2	-0.0120	0.0249	-0.48
South Dakota 3	0.1482	0.0235	6.31***
South Dakota 5	-0.0019	0.0239	-0.08
Year1999	-0.0489	0.1393	-0.35
Year2000	0. 425	0.0836	5.09***
Year2001	0.8084	0.0733	11.03***
Year2002	1.0269	0.0713	14.40***
Year2003	1.2089	0.1787	6.77 ***
Year2004	1.3259	0.1094	12.12***
Year2005	2.2674	0.0708	32.01***
Year2006	2.5946	0.1241	20.91***
Year2007	6.7562	0.1736	38.92***
Year2008	2.3834	0.2691	8.86***
Year2009	2.6537	0.2367	11.21***
Year2010	5.9169	0.1795	32.97***
Year2011	3.1941	0.1273	25.10***
Year2012	3.5534	0.1767	20.11***

Note:

- Model R-square = 0.9919
- ***, **,* denote coefficients significantly different from zero at 1%, 5%, 10% levels respectively
- For the district dummy variables, Minnesota 1 is assigned as the base.

An estimation of marginal values for the various quality characteristics using Equation 12 and standard t-statistic using Equation 13 are display in Table A-4 below

Table A-4: Marginal Value of HRS Wheat Characteristics, 1998-2012

Characteristics	Marginal Value ($/bu.)	Std. Error.	t - Statistics
Protein:			
District	0.3366	0.1261	2.67***
Other districts' X district	-0.0023	0.0022	-1.03
Other States' X district	-0.0266	0.0095	-2.79***
Significant data point[9]	96.5%		
90% confidence interval [10]	[0.129 - 0.545]		
Test Weight:			
District	0.1165	0.0816	1.43
Other districts' X district	0.0001	0.0001	1.15
Other States' X district	-0.0025	0.0013	-1.97**
Significant data point	18%		
Shrunken/Broken Kernels:			
District	- 0.0224	0.2812	-0.08
Other districts' X district	-0.0487	0.0602	-0.81
Significant data point	0%		
Damaged Kernels:			
District	-1.0846	0.2295	-4.72***
Other districts' X district	-0.0310	0.0218	-1.42
Significant data point	0%		
District & Yearly Dummy Variables			
Minnesota 4	0. 0715	0. 0736	0.97
Montana 2	0. 6598	0. 0867	7.61***
Montana 3	-0. 0242	0. 0795	-0.30
Montana 5	0. 6881	0. 0837	8.22***

Significant data points are the percentage of data points that are statistically significant and of the expected sign.

[10] Confidence intervals was calculated using $marginal\ \text{Value} \pm 1.64 * Se$

Montana 10	0. 6088	0. 1127	5.40***
North Dakota 1	-0. 5327	0. 0844	-6.31***
North Dakota 2	-0. 4510	0. 0828	-5.45***
North Dakota 3	-0. 2501	0. 0847	-2.95***
North Dakota 4	-0. 4907	0. 0843	-5.82***
North Dakota 5	-0. 2885	0. 0824	-3.50***
North Dakota 6	-0. 2302	0. 0818	-2.81***
North Dakota 7	-0. 3604	0. 0857	-4.21***
North Dakota 8	-0. 4428	0. 0852	-5.19***
North Dakota 9	-0. 1011	0. 0820	-1.23
South Dakota 1	-0. 3210	0. 0818	-3.92***
South Dakota 2	-0. 0120	0. 0750	-0.16
South Dakota 3	0. 1482	0. 0751	1.97**
South Dakota 5	-0. 0019	0. 0771	-0.03
Year1999	-0. 0489	0. 1370	-0.36
Year2000	0. 4252	0. 1108	3.84***
Year2001	0. 8083	0. 0943	8.57***
Year2002	1.0268	0. 0891	11.51***
Year2003	1.2088	0. 1517	7.96 ***
Year2004	1.3259	0. 1553	8.53***
Year2005	2.2673	0. 0814	27.82***
Year2006	2.5946	0. 1002	25.88***
Year2007	6.7562	0. 1277	52.88***
Year2008	2.3834	0. 1698	14.03***
Year2009	2.6537	0. 2271	11.68
Year2010	5.9169	0. 1700	34.80***
Year2011	3.1940	0. 0966	33.04***
Year2012	3.5534	0. 1227	28.94***

Note:

- Model R-square = 0.9919
- ***, **,* denote coefficients significantly different from zero at 1%, 5%, 10% levels respectively
- For the district dummy variables, Minnesota 1 is assigned as the base.

The estimated coefficients for the district dummy variables reflect premiums and discounts relative to the district not included. Because the district not included is closest to the principal Minneapolis terminal market, the parameter estimates are approximations of transportation costs from each district. As shown in Table A-4, those districts farthest from the base price location received large discounts/premiums. In general, the district dummy values seem to suggest the spatial price relationship as a result of transportation and handling charges.

In Table A-4 above, each marginal value for protein and test weight were calculated using Equation (12) and the standard errors were calculated using Equation (13). Ninety seven percent of observations for protein were significantly different from zero at the 10% level and of the expected positive sign. Using this information in calculating the normal confidence interval, a 90% confidence interval was estimated to be between \$0.129 and \$0.545 /bushel. This shows a wider confidence interval for marginal value of protein. This indicates greater variability around the point estimate found in this study. Thus, a greater uncertainty of premiums values for protein. Parcell and Stiegert estimated a confidence interval between \$0.046 /bushel and \$0.074 /bushel for DNSW, which has a lesser variability around the point estimate based on a smaller sample size. One important implication is that wheat producers' varietal choice decisions depends on the yields and price volatility at the time of planting as well as wheat characteristics.

The estimated parameters for protein were positively related to district prices ceteris paribus; hence, if protein goes up by 1%, the marginal value of a bushel goes up by 34 cents. Because HRSW prices were negatively related to other states' *X* district protein, when the level of protein in other states' *X* district increased, the marginal value of a bushel of HRSW would decline by 2.66 cents in *X* district's state, indicating the presence of spatial competition in HRSW quality characteristics. Also, the coefficient for other district's *X* district signifies that if protein in HRSW increases, it would not have any effect on *X* district prices because the coefficient is not significant. For test weight, 18% of its marginal values at each data point were significant at 10% level and of the expected positive sign. The estimated parameter for test weight in own district prices was statistically insignificant, that is, it has no marginal effect on prices, but other states' *X* district responded negatively in *X* district's state. Thus, as the test weight in other states' *X* district increased, the marginal value of a bushel of HRSW declined by 0.25 cents in *X* district's state, indicating the presence of spatial competition in HRSW quality characteristic. Aside from protein and test weight, two additional grading characteristics were analyzed in our hedonic model: shrunken and broken kernels and damaged kernels. For damaged kernels, none of the marginal values at each data point were statistically significant but of the expected negative sign. Additionally, none of the marginal values for shrunken and broken kernels were statistically significant, which aligns with our hedonic model expectation.

In conclusion, the results showed a slight difference in values; however, they were not significantly different from the previous described results. This provides us with further support in being able to compare this study's wheat characteristic values to Parcell and Stiegert's study, with no indication that inflation contributes in a significant way to wheat characteristic valuations. But in all, the study found that the marginal values of protein were affected by the level of protein in other districts' *X* district and by the level in the other states' *X* district.