The Value of Weather Forecasts to the Marketing of Durum Wheat

by Cheryl Mayer

A thesis
presented to the University of Manitoba
in partial fulfilment of the
requirements for the degree of
Master of Science
in
Agricultural Economics

September 1997

Winnipeg, Manitoba

0-612-23417-7

THE UNIVERSITY OF MANITOBA

FACULTY OF GRADUATE STUDIES

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ABSTRACT

The purpose of this study is to determine if post harvest durum prices are related to spring and summer weather conditions in the Canadian prairie provinces and North Dakota. The value of long range weather forecasts were evaluated in terms of more accurately forecasting prices as well as determining a strategy that the Canadian Wheat Board could utilize in terms of forward contracting different quantities of durum during the growing season.

First, a model is specified to predict the post harvest prices of durum using only market information. A post harvest supply variable is added to reflect the yearly change in durum supply. The models are analyzed to determine the importance of durum supply in predicting post harvest prices. From these models weekly prices for durum are forecasted from September to November from spring and summer prices and supply information.

The durum price forecasts from September to November are used in decision analysis models. The decision analysis models are used to determine the optimal quantity of durum to forward contract on a weekly basis during the spring and summer. The decision model that does not use weather information is more limited than the models that use weather information in the quantities it can recommended to forward contract. The success of the different decision analysis models is determined by the revenue generated from each of the models marketing strategies recommended throughout the spring and summer.

It was found that in late May and early June changes in durum supplies had an effect on post harvest prices of durum. However the addition of the durum supply information in the summer months did not significantly reduce the forecast error of durum prices after

harvest. During the summer months an average price change has a greater effect on post harvest prices of durum than an average change in yearly durum supply. Presumably other factors such as export demand and government programs are more important to durum prices during the fall than the supply of North American durum.

From the decision analysis models it was found that forward contracting durum during the spring and summer improved the marketing of durum on average. The weather information that allowed the decision model some flexibility with respect to the quantities forward contract added more value again to the marketing of durum. Therefore weather information adds more value to the marketing of durum wheat through the determination of an appropriate marketing strategy rather than through its importance in forecasting durum prices in the fall.

ACKNOWLEDGMENTS

I would like to express my gratitude to Atmospheric Services for the financial support. I would also like to thank my major Advisor, Dr. D.F. Kraft for guiding me through the rigours of economic research. I would also like to thank the other members of my committee, Dr. M. S. Boyd, Dr. L. Rigaux and Dr. P. Bullock for their valuable input.

Thank you to all the members of the Department of Agricultural Economics and Farm Management, especially Bonnie and Debra, for their support.

Special thanks to my parents for their continuous support and encouragement throughout my life as a student. Finally I would like to thank Holly for her advice and encouragement and Lyle for always believing in me.

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Chapter I

Introduction

1.1 Introduction

In this chapter, the value of information to agricultural markets is discussed, specifically the value of weather information. The case of durum wheat and the Canadian Wheat Board is presented in terms of the contracting process and the market characteristics. Durum wheat does not have a futures market where information is revealed about future cash market prices. The closest substitute for a durum futures market is the hard red spring wheat futures market so tests are done to see if the hard red spring futures market can be used as a reliable indicator of future durum cash prices. Then the purpose and outline of the study are given.

1.2 Value of Information

Davis (p. 42) defines information as data presented in a form that is valuable for decision makers. Decision makers gather information with the intention of reducing the uncertainty around future events and thus, improving their decisions concerning future events. The value of information is evaluated by the effect the information has on the resulting decisions.

1.2.1 Market Intelligence

The function of market intelligence is to collect, interpret and distribute a variety of market information. Market participants require good information to make successful decisions and to allow the market system to operate in an efficient manner. Information about price, quality, storage and transportation is pertinent to the establishment of an efficient pricing system that includes well informed buyers and sellers. Market information is researched through both private firms and government agencies. The reflection of this information through market prices, improves marketing efficiency.

Market efficiency is defined by the ability of the market to transmit information into prices. Defined by Fama (1970) an efficient market is a market where past prices "fully reflect" all available information. Jensen (1978) improved this definition by defining an efficient market with respect to the information available. If it is impossible to make economic profits by trading on the basis of the information available, a market is efficient. The efficient market hypothesis is separated into three versions, specified by different information sets.

The weak form of the efficient market hypothesis claims that prices reflect all information contained in past prices. If this is true then no information about past or present prices or volumes is useful in determining a pricing strategy. Semi-strong efficient markets reflect all publically available information. The strong form efficiency requires all information, public and private, be reflected in the price. Private information includes information possessed only by corporate insiders such as the Canadian Wheat Board. If a market exhibited strong form efficiency the CWB could not obtain any information that would not have already been accounted for in the market's prices. In this case studying information about the determinants of prices will not be useful in determining a pricing strategy.

One way of evaluating weak form efficiency is through technical trading rules.

Technical analysis is a method of analyzing markets using only market data, such as prices and volume, to predict future price movements. If a market is efficient in the weak form, then technical trading strategies will not generate profits, because the information from past prices is already reflected in the market. Research which has found evidence of profitable trading systems and therefore reject the weak form of the efficient market hypothesis include Peterson and Leuthold (1982) which looked at the hog futures market; Murphy (1986) which studied publically-offered futures funds and; Boyd and Brorsen (1991) study of seven futures commodities. Boyd and Brorsen also examined the factors that affect the returns from a technical trading system as did Irwin and Brorsen (1987). Both studies found that increased price uncertainty and variance are positively related to technical trading returns.

Milonas (1987) looked at the existence of semi-strong market efficiency in the cash markets of wheat, corn and soybeans. He hypothesized that prices reflect information, such as USDA crop size forecasts, which is not publically announced by a government agency, but successfully forecasted by private agents. The uncertainty of crop size is attributed to yield as determined mainly by weather. Although the USDA is responsible for releasing crop forecasts at specific dates, private agencies produce their own reports to outguess USDA reports.

The price reactions to the USDA reports indicate whether the market participants were prepared or caught by surprise by the USDA forecasts. Fortenbery and Sumner (1993) also studied whether the release of USDA crop reports changed the overall perception of crops supply and demand by studying the futures and options markets of corn and soybeans. A change in a commodity's price level after the release of a USDA crop forecast report indicates the news was unanticipated.

Both studies found that USDA crop forecasts are news worthy. However, when futures prices are at or near the government loan rate, the change in price levels is significantly smaller. Milonas also found that price changes in response to the release of crop reports become less significant after the release of the initial report of the crop year. Baur and Orazem (1994) also found this to be true for the orange juice market in the U.S. Public information that results in price changes consistent with the information's contents is not fully anticipated by the market place and is therefore useful. However, information released at different points during the growing season results in different levels of price changes and so the information is of diminishing importance to the market participants throughout the growing season.

Other studies have examined whether prices adjust in response to unanticipated but not to anticipated information in the USDA reports. If the private sector anticipates accurately government production estimates then government reports will contain no surprises. Thus, the private sector is skillful in evaluating conditions such as weather and the release or government reports would not be expected to cause a change in the market price level. If there is a change in price level after the release of a government report then it contained information the private sector was not able to forecast.

Grunewald et al.(1993) used private survey forecasts as the anticipated information about live cattle futures. This information is released prior to the USDA report. Therefore if the market is efficient, the price at the release of the USDA report should incorporate the private forecast and any change in price is due to the difference between the USDA and the private forecast. The futures price of live cattle was found to react to unanticipated information. Colling and Irwin (1990) also found that live hog futures prices react only to unanticipated information in government reports, not to anticipated information. This supports the efficient market hypothesis as only new unanticipated information causes the market to respond.

The previous studies have shown how supply and demand uncertainty affect price changes, however, the supply of information into the market also affects volatility or price variance. Market participants who make their pricing decisions based on both expected returns and risk perception would find economic value in information that reduces their risk, but does not change their expected returns. Information affects the distribution of prices, therefore information that makes market participants more certain about future economic conditions would result in a narrower price distribution. The greatest uncertainty for grain is yield uncertainty related to weather during the growing season.

Kenyon et al. (1987) found that grain futures volatility is affected by the season. This volatility is greatest during periods of yield uncertainty. The impact of USDA crop forecasts on risk perception is examined by McNew and Espinosa (1994) through the corn and soybean futures and options markets. The results show a large reduction in uncertainty in the day following the release of the crop forecast, but no significant change in the mean expected price of the market participants. The USDA crop forecast provides information which makes the market more certain about supply, and thus has economic value.

1.2.2 Weather Information

Weather creates an environment of uncertainty for decision makers in the agricultural sector. This uncertainty can have significant effects on the economic activity of agricultural businesses, such as farms. Therefore there could be value in information about future weather events that would allow decision makers to minimize the adverse effects of weather and exploit the positive effects. In order for weather information to have value for any sector though, it must have the potential to alter the decisions of management. Flexibility in decision making is required for the decision maker to be able to take new information and reevaluate the decision choices available (Sonka et al., 1987).

Most agricultural studies have related the value of weather information to the individual farmer. There are two ways that farmer's decisions can be affected by weather. First by an impact on production and second by altering the expected price changes. There are a number of studies that relate weather information to agricultural productivity. Generally they concentrate on situations with short lead times and evaluate the value of weather forecasts through improved agriculture productivity. Agriculture production can be improved through irrigation scheduling (Bosch and Eidman, 1985), frost protection (Baquet et al., 1976; Stewart et al., 1984), or by altering input choices, such as fertilization rates (Sonka et al., 1982).

However, there are few studies relating the impacts of weather information on market prices. Lave (1963) examined the value of weather information to the individual raisin producer in California through its impact on the market prices. He concluded that raisin producers would be better off without improved weather information because of the effects on production and an inelastic demand. Babcock (1990) also studied the impact of weather information on market prices as they relate to the individual farmer and found contrasting results to Lave.

"It can be difficult to assess the value of weather forecasts when they are used together with other information in a dynamic process" (Stewart et al., 1984). A detailed description of the research challenges and opportunities associated with valuing weather information is provided in Sonka et al. (1987).

1.3 The Case of Durum Wheat and the Canadian Wheat Board

1.3.1 Contracting Process

The Canadian Wheat Board (CWB) is the sole legal exporter for wheat and barley grown in Western Canada, including durum. It also has a marketing monopoly on these grains for domestic industrial uses. Producers sell their durum to the CWB and the CWB then obtains the highest price possible for the durum entrusted to it and returns as much as possible back to the producer. The CWB operates a price pooling system. The initial payment to producers is based on market projections, and if receipts are greater than the initial payment plus administrative costs, a final payment is returned to the producer at the end of the crop year. A selling strategy is employed by the CWB to maximize the overall receipts and return the best possible average price to the producer. Part of the CWB's selling strategy includes forward selling durum during the growing season. This has some risk associated with it because the result of the harvest is not known at the time the forward contract is entered into.

The durum market does not have a futures market where buyers and sellers can offset the uncertainty of unknown prices for sales throughout the year. The closest substitute for a durum futures market is the hard red spring futures market. However, the durum and hard red spring markets often move independently because different factors affect the supply and demand for durum and HRS wheat. When the price of durum is high during the growing season a forward contract could be entered into so that the high price of the growing season is guaranteed when the crop is harvested and ready for sale. The timing of the forward contract is important, because if prices continue to rise profits will be reduced by the forward sale. If prices fall after the grain is forward sold then profits are increased by the sale. Whether or not prices will rise or fall during the growing season will be affected by stocks and by the expected harvest of the new crop. The yield of the new crop is determined to a great extent by the growing conditions.

The quantity of grain that can be forward sold is also important. If good growing conditions extend through the growing season a large quantity of grain will have to be marketed. However, at the time of the forward sale the amount of Canadian production is unknown. It is risky to enter into a forward sale for a large quantity of grain if yields deteriorate prior to threshing because of excessive moisture or frost. Profits may be lost if more grain is harvested than forward sold at a high price or too much grain was forward sold and cannot be delivered.

1.3.2 Market Characteristics

1.3.2.1 Production

(i) World

World durum production has fluctuated between a low of 20.8 million tonnes (Mt) in 1988 and a high of 35 Mt in 1991 (Table 1.1). Durum wheat is grown only in a few regions. The major producers besides Canada and the United States are the European Union (EU), the former U.S.S.R. and Turkey. The United States, Canada and the EU produce most of the worlds high protein durum which can be used to manufacture pasta. These three countries supply approximately 95 percent of the world durum exports. The EU has been increasing its production of durum over the last 15 years to a high of 11.3 Mt in 1991 and was projected to produce 6.8 Mt in 1995. Canada and the U.S. have been producing between 2 and 4 Mt each year for the last 15 years each with a low of less than 2 Mt in 1988, due to drought.

(ii) Canadian

Canadian durum producers are mainly family-run operations with a crop mix including feed grains, barley, canola, flax and other spring wheats. Over the last 15 years Canadian durum production has ranged from a high of 4.6 Mt in both 1991 and 1994 to a low of less than 2 Mt in 1988. Most of Canada's durum is produced in the Palliser Triangle of southeast Alberta and southwest Saskatchewan. Although some durum is produced as far east as south central Manitoba. Over the last 10 years durum acreage in Canada increased to a high of 6.5 million acres in 1989 and then decreased to a low of 3.56 million acres in 1993 (Table 1.2). However durum acreage has increased since then to 5.35 million acres in 1995.

(iii) United States

U.S. durum producers are also primarily family-run operations. U.S. farmers producing durum also grow a wide range of alternative crops to durum including spring wheat, sunflower seeds, barley, flax and other winter wheats. Over the last 15 years U.S. durum production has ranged from a high of 4.9 Mt in 1981 to a low of 1.2 Mt in 1988. Most of the durum produced in the U.S. is grown in the Great Plains areas of North and South Dakota, Montana and Red River Valley of Minnesota. A small percentage of U.S. durum is produced in Arizona and California under irrigation. Weather plays substantially less of a role in these areas than in the northern production areas in the U.S. Durum wheat acreage harvested over the last 10 years has been relatively constant. Acreage reached a low of 2.1 million acres in 1993 and a high of 3.57 million acres in 1989 (Table 1.2).

(iv) Yields

From 1980 to 1995 durum yields in Canada and the U.S. have generally moved in the same direction. However the 15 year average yield for the U.S. is approximately 4 bu/acre more than the Canadian 15 year average (Table 1.2). Over these 15 years there is no obvious trend or pattern in the durum yields. The lowest yields are in 1980 and 1988 which were periods of drought. The highest yields were in 1992 and 1993, which were years in which sufficient rain fall was received. The key factor in the fluctuation of durum yields is the weather, especially rainfall during the growing season.

(v) Inventory and Carryover

The inventory of durum carried over from one growing season to the next represents the buffer stock in case lower levels are harvested. Carryover stocks rest exclusively in Canada, United States and Europe. Durum wheat carryover from the three top producing nations, Canada, United States and European Union, was the lowest in 15 years for the 1994-95 crop season at 3.2 Mt (Table 1.3). This represents just over ten percent of expected consumption. Until the 1988-89 crop season when drought substantially reduced durum yields, durum carryover was increasing each year to 7 Mt in 1987-88, and was reduced to 4.3 Mt the next season. Carryover increased again from 1989-92 and then decreased to its current 15 year low.

1.3.2.2 Consumption

Durum is used mainly in the production of pasta in Europe and North America. World consumption since 1988 has increased from 25 million tonnes to 31 million tonnes in 1994, however consumption in 1995 decreased by almost 3 million tonnes due to lower production. North African countries are large consumers of durum, using it to produce couscous and unleavened bread. Although these countries produce durum, they all rely upon imports to meet their annual requirements. Very little durum is consumed in Asia.

(i) Durum Characteristics

Durum wheat is considered the hardest of all wheats, which makes it the preferred wheat in the manufacturing of pasta. Higher protein content is associated with kernel hardness and therefore improve durum for use in pasta production. The protein content positively affects the cooking quality of the pasta products. The protein content in wheat is affected by the growing conditions during the spring and summer.

Durum wheat is milled to obtain semolina and durum flour which are used in the manufacturing of pasta products. Semolina is a relatively coarse granular product and is the preferred milled product from durum, although the flour, a finer product, can also be used for processing. The goal of semolina milling is to produce the maximum amount of utilizable product of good colour. The quality and yield of semolina depend on a number of factors. The first being the grade of wheat which is determined by the variety, test weight, vitreousness, and the number of kernels from other wheat classes mixed in with the durum wheat.

In order to qualify for the top grades producers in Canada must plant a variety of durum wheat that is registered. Durum wheat varieties that are registered have been proven to display quality characteristics superior to those varieties which are not registered. Durum wheat must also score a high test weight to qualify for the top grades in Canada. Each grade has a minimum allowable test weight. Test weight is a measure of the soundness of the wheat kernel. A sound kernel is plump, mature and essentially free of damage. Grain that has a low test weight has thin and shrunken kernels. Factors that affect test weight are weather related such as frost, heat stress, drought and diseases such as rust.

Vitreousness is another quality characteristic of durum which millers are most concerned with. Vitreousness means the kernels are not starchy and therefore of good milling quality. Starchy kernels are softer and lower in protein content than vitreous kernels. For wheat to qualify for the top grade in Canada it must be of at least 80% vitreous kernel content. The Italian millers also specify a minimum level of vitreous kernel content when purchasing durum.

The amount of other grains mixed in with the durum also affect the milling quality of durum. Grains that can be removed easily are not the problem, it is the grains of similar size and shape such as the common wheats, which have a lower milling quality than durum. These common wheats yield a lower amount of semolina than durum, therefore when it is mixed in with durum, the overall semolina yield of durum is lower.

1.3.2.3 Trade

The world importers of durum include Algeria, Italy, Venezuela, Tunisia, Libya and Japan, as well as the United States and the former U.S.S.R. North Africa is the major durum importing region of the world. Here durum wheat is used to produce couscous, which is the staple food. Algeria imports the most durum with 3.5 million tonnes (Mt) in the 1994-95 crop season (Table 1.5). The former U.S.S.R. has also been a large importer of durum wheat in the past (1.8 Mt in 1991-92), but has recently reduced imports of durum to 22 000 tonnes in 1994-95.

Canada, the U.S. and Europe produce approximately half of the world durum production, and account for almost all of world durum exports. Over 75 percent of Canadian durum wheat is exported. Table 1.4 shows that annual durum exports have grown from just over 2 million tonnes in the early 1980's to 4 million tonnes by 1994-95. The value of the crops to Canadian farmers also reached a high in 1994-95 at $899 million and a low in 1985-86 at $251 million (Table 1.6). Generally the value of the durum crop to Canadian farmers is reflected in the price and production trends for the period. For example, in 1988-89 the tonnes sold decreased by almost 1 million tonnes due to low production, but the value of sales only decreased by $25 million because durum prices were high in 1988-89. Both the value and volume of Canadian durum sales reached a 15 year high in 1994-95.

1.3.2.4 Price

(i) Durum vs Hard Red Spring Wheat

Durum wheat and hard red spring wheat prices followed a similar pattern over the period 1980 through 1995, however durum wheat has generally been at a premium to hard red spring (HRS) wheat (Figure 1.1). In 1980 durum wheat prices were at least $1/bu higher than HRS prices and at times as much as $2/bu higher. However from 1981-83 durum prices remained close to HRS prices, and even dropped below HRS prices for a few months in 1982. Durum prices were again below HRS prices for most of 1985, until wheat prices fell in 1986 and brought durum and HRS prices together. Wheat prices trended upward, after the fall in 1986, to 1989, with durum obtaining a premium over HRS. Wheat prices fell again in late 1989 and levelled off through 1990 until they rose again in 1991 with HRS at a premium this time to durum. Large price increases in wheat from 1993-95 moved durum back into a premium position over HRS. The premiums received during this period were substantial, similar to those received in 1980.

(ii) Inventory

Wheat prices for any variety of wheat are very sensitive to shifts in supply. This is because demand is relatively stable and inelastic to price changes therefore supply shifts play an important role in determining wheat prices. Generally when durum carryover is low prices rise which was the situation from 1980-82 and again from 1993-95 (see Figure 1.2). The drought of 1988 also reduced stocks and caused durum prices to rise and in 1986 when carryover was at a high the price of durum fell. During the early 90's prices were falling and supplies were at an all time high.

(iii) U.S. Farm Programs

The USDA administers a number of programs to assist wheat producers by supporting farm prices and income, including durum producers, but does not specifically target them. Government grain reserves and price-and-income support programs have had effects on the U.S. durum market. The Commodity Credit Corporation (CCC) acts as a financial institution by borrowing money from the Treasury to make payments to farmers and repays the Treasury with loan payments. The CCC also maintains grain reserves. Most of the U.S. durum grain carryover goes into the CCC reserves or the farmer-owned-reserves (FOR). Stocks in reserves are likely to be of lesser quality partly because farmers usually sell their best quality grain commercially and partly because grain in storage may be old and lose its quality over time. When stocks are used due to a shortage of grain, the overall quality of grain tends to be lowered. The emptying of reserve stocks may also prevent price from rising as high as they otherwise may have in a drought situation. This was true in 1988 and created the risk of shortage and high prices in 1989 because of the small stock-to -use ratio, which was the result of depleted reserves in 1988.

One of the 1985 U.S. Farm Bill's initiatives was to lower grain stock piles. This was done through acreage reduction programs. The amount of land idled was based on the level of stocks. Another U.S. program that affected wheat acreage was an acreage diversion program that allowed farmers to under plant their permitted wheat acres and still, under some conditions, receive deficiency payments on a portion of the under planted acreage. The land that was permitted not to be planted must be used in conserving uses.

The Export Enhancement Program (EEP) is another program that was designed to help increase U.S. exports of grain, by lowering the price of U.S. grain in foreign markets. Exporters would receive a bonus from EEP equalling the difference between the world price and the U.S. domestic price, if the world price was lower than the domestic price. Under EEP the U.S. share of durum export sales has decreased from 41% of world durum exports in 1986-87 to 19% in 1991-92.

The Federal Agriculture Improvement and Reform Act of 1996 (FAIR 1996) is radically different than its predecessors (ERS 1996). No longer are prices guaranteed and payments are decoupled from wheat receipts. Market prices are likely to be more variable since the incentive for the government supported storage no longer is present.

(iv) Durum Price Variability

Growing Season Relative to the Rest of the Year

The variability of durum prices during the months of June to September (the growing season) is compared to the variability of durum prices during the rest of the year (non-growing season), in an attempt to identify the variability caused by weather in North America. During the growing season is when weather causes uncertainty in durum supplies and price variability should increase especially when inventories are relatively lower. North American weather does not affect the durum market during the other months of the year and so any variability in prices cannot be attributed to growing conditions in Canada and United States. Therefore weather is hypothesized to play an important role if durum price variability in the growing season exceeds that of the non-growing season.

Durum Prices Relative to Hard Red Spring Wheat (Cash and Futures)

Durum wheat, unlike hard red spring wheat, is grown only in a few regions and normally sells in a "thin" market. Changes in the supplies of durum play a more important role in determining prices than shifts in demand. Consumption is relatively stable given that preferences of consumers for pasta products do not change marketably from year to year and the number of consumers grows slowly. Weather conditions are the largest factor affecting durum supply during the growing season. Furthermore, it is hypothesized that the durum market reacts differently to supply uncertainty created by North American weather than the HRS market, both cash and futures. The durum market does not have a futures market, but the HRS market does. HRS and durum are similar commodities though, making the HRS futures contract the closest futures contract for the durum market to follow. However, HRS wheat is grown widely through the Northern hemisphere and subjected to a wider range of geographic weather events than durum wheat.

Data

Both durum and hard red spring cash prices are from the Minneapolis Grain Exchange, obtained from the USDA Weekly Grain and Feed Market News from 1980 through 1995. The daily prices were used to find weekly price changes from Wednesday to Wednesday. The weekly price changes for both durum and HRS from June to

September are separated from the rest of the year's weekly changes and called the growing season price changes. The rest of the year's price changes are the non-growing season price changes. The HRS futures prices are from the Minneapolis Grain Exchange's December contract.

Analysis

Durum weekly price changes are used to compare the variability between the growing and non-growing season. The variability in the growing season is greater than that of the non-growing season for the weekly price changes (Table 1.7). The distribution of weekly price changes in the growing season has a greater frequency of large price changes compared to the distribution of non-growing season weekly price changes. The non-growing season has a greater frequency of small price changes than the growing season distribution (see Figures 1.3-1.4). The years that produced the largest price changes were, 1980, 1984, 1986, 1988 and 1994. A chi square test comparing durum weekly price changes in the growing season against the non-growing season resulted in a chi square of 59. The same test done for HRS resulted in a chi square of 70. These results lead to the conclusion that the distribution of price changes in the growing season is different from that of the non-growing season both in the durum market and the HRS market.

The weekly price changes for durum compared to HRS also show different frequency distributions (see Figures 1.5-1.6). The difference between these distributions is in the medians and the tails of the distributions. Small or no weekly price changes are more frequent in the durum market than in the HRS market, while the HRS distribution has more weekly price changes between a plus or minus 3% change. However, when durum prices adjust they do so with changes that more frequently exceed 6.5% than HRS. The durum and HRS markets are different from each other, which is illustrated by chi square tests that result in a chi square of 98 in the growing season and 144 in the non-growing season.

The HRS futures prices were compared to the durum cash prices to see if the HRS futures can be used as an indication of the durum cash prices. The comparison was done by calculating the price change over thirteen weeks starting the first week in June to the last week of August, for both the futures and the cash prices. If the HRS futures is a good indicator for durum cash prices, then the difference between the thirteen week price changes for the cash and futures should be zero. These differences were averaged over the sixteen weeks for each year and for each week separately over the period 1980 to 1995 (Table 1.8). There was no consistent difference between the prices either by year or by week. The standard deviation was also inconsistent for all periods. Thus, the HRS futures prices cannot be used as a reliable indicator for upcoming durum cash prices.

Changes in Durum Prices in the Growing Season Relative to the Rest of the Year

Yearly price changes (from May to May) compared to the price change over the growing season (from May to Sept.) are illustrated in Figure 1.7. Analysis of these price changes shows that most of the annual price adjustment takes place during the growing season. Only a few years resulted in small percentage changes in the price of durum during the growing season. The rest of years showed large changes in price over the growing season relative to the change over the entire year.

1.4 Purpose of Study

The purpose of this study is to see if weather information is reflected in the durum market, and if it is not to see how much predictive power weather information has in forecasting durum prices. The second purpose is to find out if weather information could affect the marketing strategy of a single desk seller such as the CWB though forward contracting during the growing season.

1.5 Outline of Study

The remaining portion of the study deals with forecasting prices, decision strategies for marketing durum, analysis of results, and conclusions from the forecasts and marketing strategies. Chapter two discusses the price forecasting models. Included is an overview of each model and a description of the weather variable, then reliability of each model's forecasts are analyzed. In Chapter three the price forecasts are used to develop a marketing strategy for each model. Decision trees are used to find the optimal marketing plan for each week. Chapter four analyzes the results of the price forecasts and the decision trees with respect to the added information of the weather variable. Conclusions and a summary of the study are in chapter five.

Table 1.1 Durum Wheat Production in the Major Producing Countries 1980-1995 Thousand Tonnes

Year	EU[1]	Turkey	Canada	United States	U.S.S.R.[2] (former)	Total
1980	4 963	4 800	2 035	2 950	N/A	26 000
1981	4 474	5 335	2 977	4 982	2 500	26 944
1982	4 345	6 125	3 121	3 970	2 000	26 478
1983	4 070	5 500	2 620	1 986	2 000	22 772
1984	6 623	6 000	2 110	2 815	1 500	25 195
1985	5 873	6 000	1 960	3 062	2 000	26 924
1986	7 238	6 000	3 897	2 665	2 500	30 008
1987	7 525	5 500	4 014	2 521	2 000	26 918
1988	6 960	4 000	1 979	1 220	2 000	20 844
1989	6 608	5 500	4 140	2 510	2 000	27 078
1990	7 398	5 500	4 197	3 332	2 000	29 321
1991	11 340	5 000	4 586	2 829	2 000	34 791
1992	9 048	4 000	3 138	2 719	2 000	28 636
1993	6 900	4 200	3 358	1 918	2 000	26 200
1994	8 000	4 000	4 689	2 640	2 200	30 600
1995[3]	6 800	3 500	4 730	2 776	N/A	27 800

1 EU-12 member states from 1980; unified Germany from 1990; EU-15 in 1994.
2 Estimated by the IGC, no official statistics available. Hence durum is not adjusted for net-weight loss.
3 Preliminary: Subject to revision.
Sources: Canada - Statistics Canada.
United States - United States Department of Agriculture.
Other Countries/Total - International Grains Council.

Table 1.2 Durum Yields and Harvested Areas for Canada and USA 1980-1995

	Canada		USA	
Year	Harvested Area mln acres	Yield bu/acre	Harvested Area mln acres	Yield bu/acre
1980	3.30	22.70	4.84	22.40
1981	4.20	26.00	5.66	32.40
1982	3.65	31.40	4.18	34.90
1983	3.50	27.50	2.49	29.30
1984	4.15	18.50	3.22	32.10
1985	4.25	16.70	3.10	36.29
1986	4.54	31.39	2.88	34.00
1987	5.40	27.30	3.28	28.25
1988	5.51	12.72	2.85	15.74
1989	6.50	23.40	3.57	26.00
1990	5.17	29.83	3.50	34.78
1991	4.92	34.24	3.20	32.52
1992	3.61	31.98	2.45	39.70
1993	3.56	34.66	2.05	33.60
1994	5.65	30.50	2.64	35.60
1995	5.35	32.49	3.36	30.48

Source: CWB Weather & Crop Surveillance Crop Database

Table 1.3 Durum Wheat Carryover Stocks in the Major Exporting Countries Local Marketing Years 1980-81 to 1994-95 Thousand Tonnes

Crop Year	Canada	EU[1]	United States	Total
1980-81	1 165	780	1 633	3 618
1981-82	1 233	543	2 885	4 661
1982-83	1 174	658	3 701	5 533
1983-84	764	993	2 694	4 451
1984-85	524	1 511	2 722	4 757
1985-86	554	1 300	3 293	5 147
1986-87	1 619	2 449	2 585	6 653
1987-88	1 626	3 101	2 259	6 986
1988-89	846	1 799	1 633	4 278
1989-90	1 362	1 618	1 361	4 341
1990-91	1 567	1 900	1 687	5 154
1991-92	2 206	4 600	1 497	8 303
1992-93	2 057	3 685	1 334	7 076
1993-94	1 702	1 585	762	4 049
1994-95	1 458	1 100	708	3 266
1995-96[2]	1 400	600	544	2 544

1 EU-10 up to 1984-85, EU-12 member states from 1985-86; unified Germany from 1990-91; EU-15 in 1994-95.
2 Preliminary: Subject to revision.
Sources: Canada - Statistics Canada.
EU - International Grains Council.
United States - United States Department of Agriculture.

Table 1.4 Exports of Durum Wheat by Principal Exporters Distribution by Quantity and Percentage of Total 1980-81 to 1994-95 (July-June)[1] Thousand Tonnes

Crop Year	Canada	EU[2]	United States	Total
1980-81	2 170	65	1 610	3 845
	(56.4%)	(1.7%)	(41.9%)	(100.0%)
1981-82	2 365	145	1 977	4 487
	(52.7%)	(3.2%)	(44.1%)	(100.0%)
1982-83	2 723	254	1 450	4 427
	(61.5%)	(5.7%)	(32.8%)	(100.0%)
1983-84	2 577	85	1 505	4 167
	(61.8%)	(2.0%)	(36.1%)	(100.0%)
1984-85	1 847	101	1 659	3 607
	(51.2%)	(2.8%)	(46.0%)	(100.0%)
1985-86[3]	1 404	1 816	1 481	4 701
	(29.9%)	(38.6%)	(31.5%)	(100.0%)
1986-87	1 990	1 029	2 088	5 107
	(39.0%)	(20.1%)	(40.9%)	(100.0%)
1987-88	2 789	1 965	1 396	6 150
	(45.3%)	(32.0%)	(22.7%)	(100.0%)
1988-89	2 034	2 796	474	5 304
	(38.3%)	(52.7%)	(8.9%)	(100.0%)
1989-90	2 847	2 274	1 502	6 623
	(43.0%)	(34.3%)	(22.7%)	(100.0%)
1990-91	3 232	2 111	1 216	6 559
	(49.3%)	(32.2%)	(18.5%)	(100.0%)
1991-92	3 091	2 567	1 335	6 993
	(44.2%)	(36.7%)	(19.1%)	(100.0%)
1992-93	2 279	2 642	1 275	6 196
	(36.8%)	(42.6%)	(20.6%)	(100.0%)
1993-94	2 903	1 171	1 185	5 259
	(55.2%)	(22.3%)	(22.5%)	(100.0%)
1994-95	4 028	1 578	994	6 600
	(61.0%)	(23.9%)	(15.1%)	(100.0%)

1 Canada: August-July.
2 EU-10 member states up to 1984-85; EU-12 member states from 1985-86; 1990-91 includes unified Germany; EU-15 in 1994-95; excludes EU intra-trade.
3 Includes semolina from 1985-86.
Because of rounding, percentages may not add.
Sources: Canada - Statistics Canada; EU - International Grains Council; United States - USDA "Inspections for Export".

Table 1.5 Imports of Durum Wheat into Selected Countries from all Sources 1980-81 to 1994-95 (June-July)[1] Thousand Tonnes

Year	Algeria	Former U.S.S.R.[3]	Italy	United States	Venezuela	Tunisia	Libya	Japan
1980-81	N/A	N/A	N/A	-	N/A	N/A	N/A	N/A
1981-82	1 325	966	953	-	165	102	30	58
1982-83	1 325	1 273	654	-	182	160	61	76
1983-84	1 286	436	602	-	207	349	133	70
1984-85	1 000	684	183	T	230	252	123	78
1985-86	2 641	676	230	T	176	114	119	84
1986-87	2 341	505	652	59	225	447	222	119
1987-88	3 164	1 276	288	176	272	270	162	116
1988-89	2 725	909	224	202	225	445	136	140
1989-90	2 640	1 102	337	179	136	320	190	138
1990-91	2 485	1 165	163	308	237	144	230	140
1991-92	2 481	1 777	138	399	272	22	317	132
1992-93	2 381	783	199	386	288	12	166	161
1993-94	2 265	2	216	437	266	33	212	109
1994-95	3 523	22	327	347	233	516	289	79

T Less than 500 tonnes.
1 Excludes EU intra-trade.
2 Excludes semolina.
3 Excludes FSU intra-trade. Historical data are not available by individual republic from the IGC.
4 From 1989-90 to 1991-92, the total understates imports due to substantial US transshipments through Canada, not itemized in official customs statistics. For 1992-93 customs data adjusted according to USDA estimates of destination of transshipment.
Source: IWC "World Wheat Statistics" 1987, International Grains Council, "World Grain Statistics" 1994 and "GMR 242".

Table 1.6 Value of Canadian Durum Sales 1980-81 to 1994-95

Year	Amount (millions of $)	Tonnes (millions)
1980-81	481	1.8
1981-82	386	1.8
1982-83	373	2.0
1983-84	445	2.2
1984-85	297	1.4
1985-86	251	1.3
1986-87	277	1.9
1987-88	399	2.7
1988-89	375	1.8
1989-90	509	2.8
1990-91	341	2.9
1991-92	384	2.8
1992-93	367	2.4
1993-94	516	2.5
1994-95	899	3.6

Source: CWB Annual Reports.

Table 1.7 Statistical Analysis of the Distribution of Weekly Price Changes for

Durum (1980-1995)

	Growing Season	Non-Growing Season
Mean (cents/bu)	-0.03	0.14
Standard Deviation (cents/bu)	4.23	2.91
Skewness	1.02	-0.21
Kurtosis	6.56	9.23

Hard Red Spring (1980-1995)

	Growing Season	Non-Growing Season
Mean (cents/bu)	-0.11	0.05
Standard Deviation (cents/bu)	4.46	2.93
Skewness	-0.26	-2.10
Kurtosis	10.35	20.07

Table 1.8 Basis Change between MGE HRS and Durum Cash Price Over a 13 Week Period Beginning the First Week of June

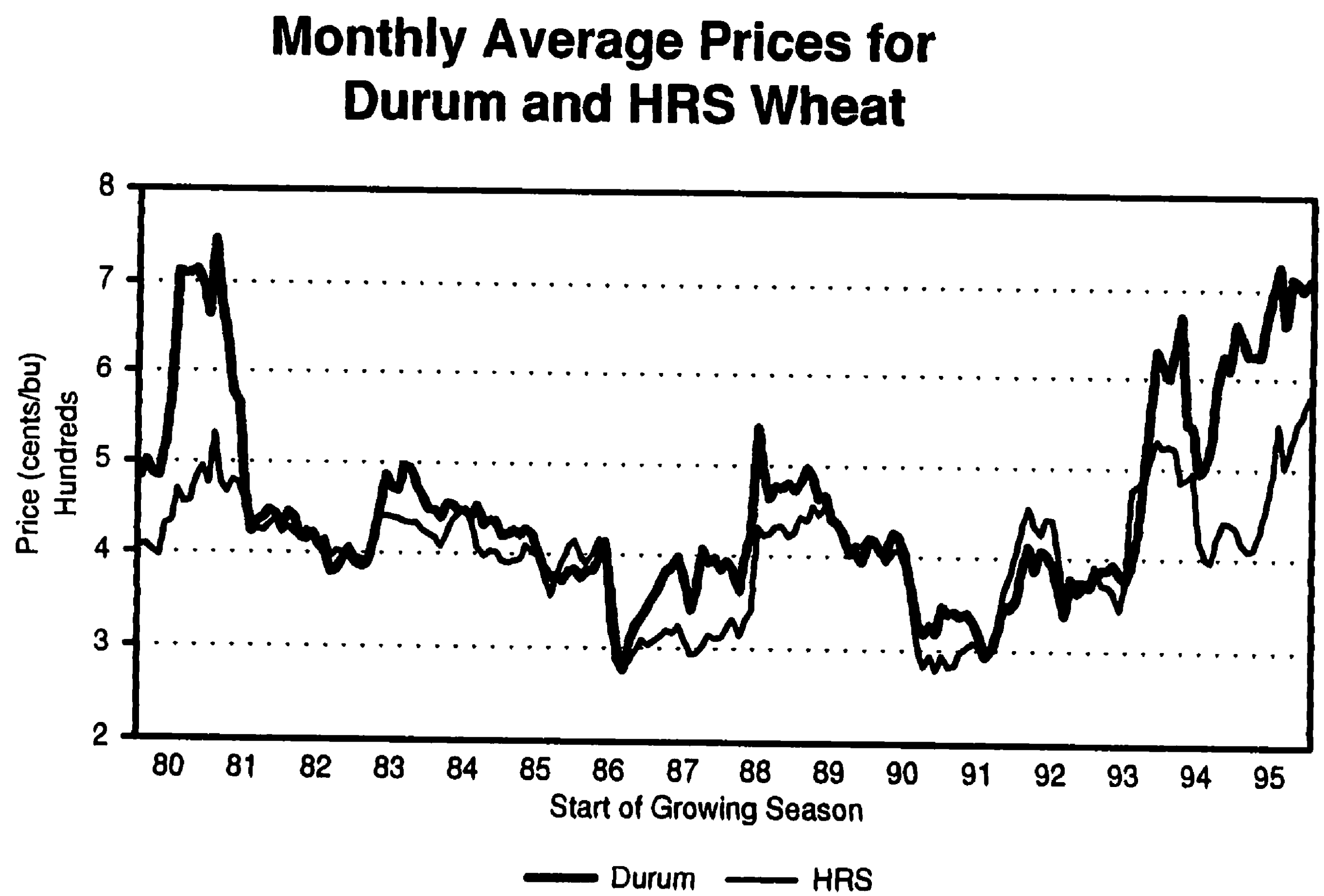
Mean and Std. Dev. For Each Year Across 16 Weeks

Year	Mean	Standard Deviation
1980	-14	57
1981	-19	20
1982	-10	26
1983	11	17
1984	-8	12
1985	17	13
1986	-26	43
1987	-21	34
1988	7	40
1989	5	19
1990	-17	16
1991	8	13
1992	-5	14
1993	-125	46
1994	64	34
1995	34	35

Mean and Std. Dev. For Each Week Across 16 Years

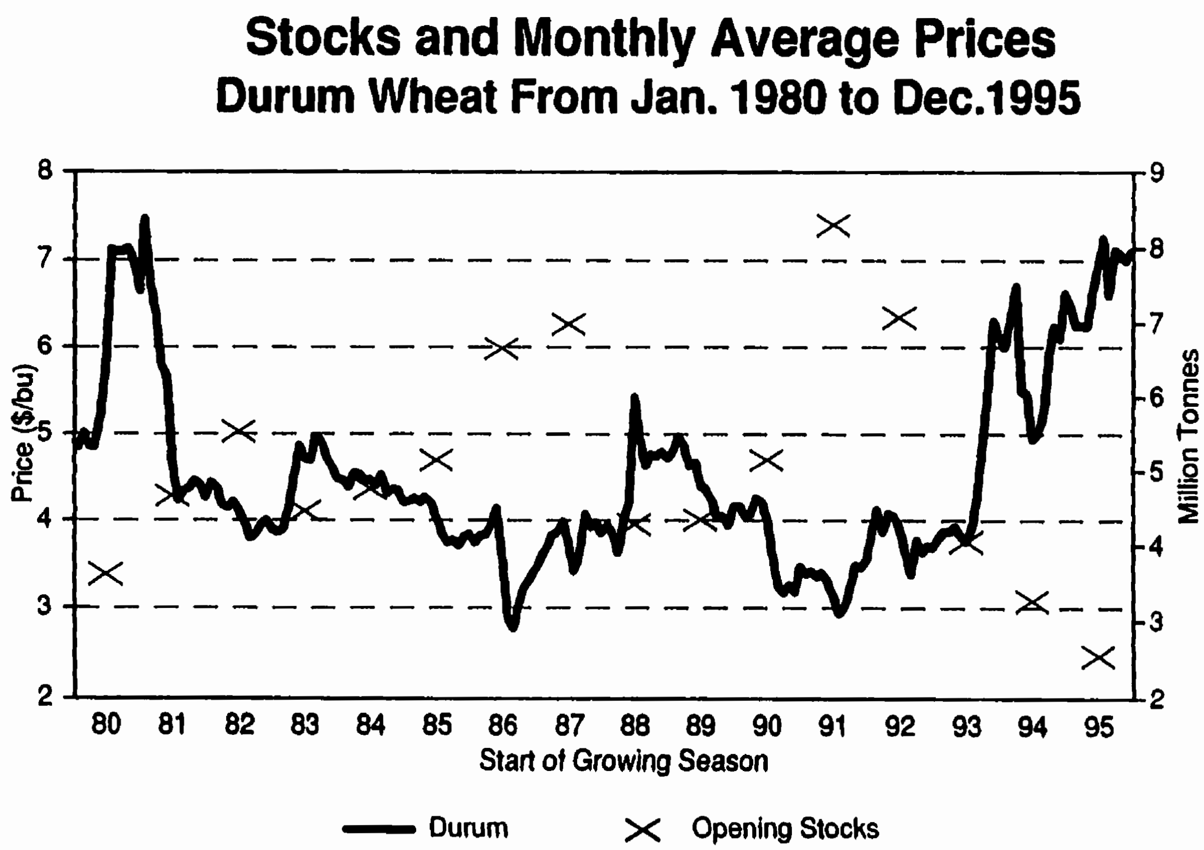
Week	Mean	Standard Deviation
1	5.5	52.8
2	-1.3	55.7
3	-10.4	40.1
4	-19.4	35.4
5	-14.6	35.5
6	-9.7	43.7
7	-16.5	48.8
8	-18.9	43.8
9	-19.2	49.8
10	-27.9	42.3
11	-24.5	34.9
12	-24.8	53.9
13	-19.8	65.7
14	-12.7	52.7
15	-16.7	48.2
16	-3.4	48.2

Figure 1.1



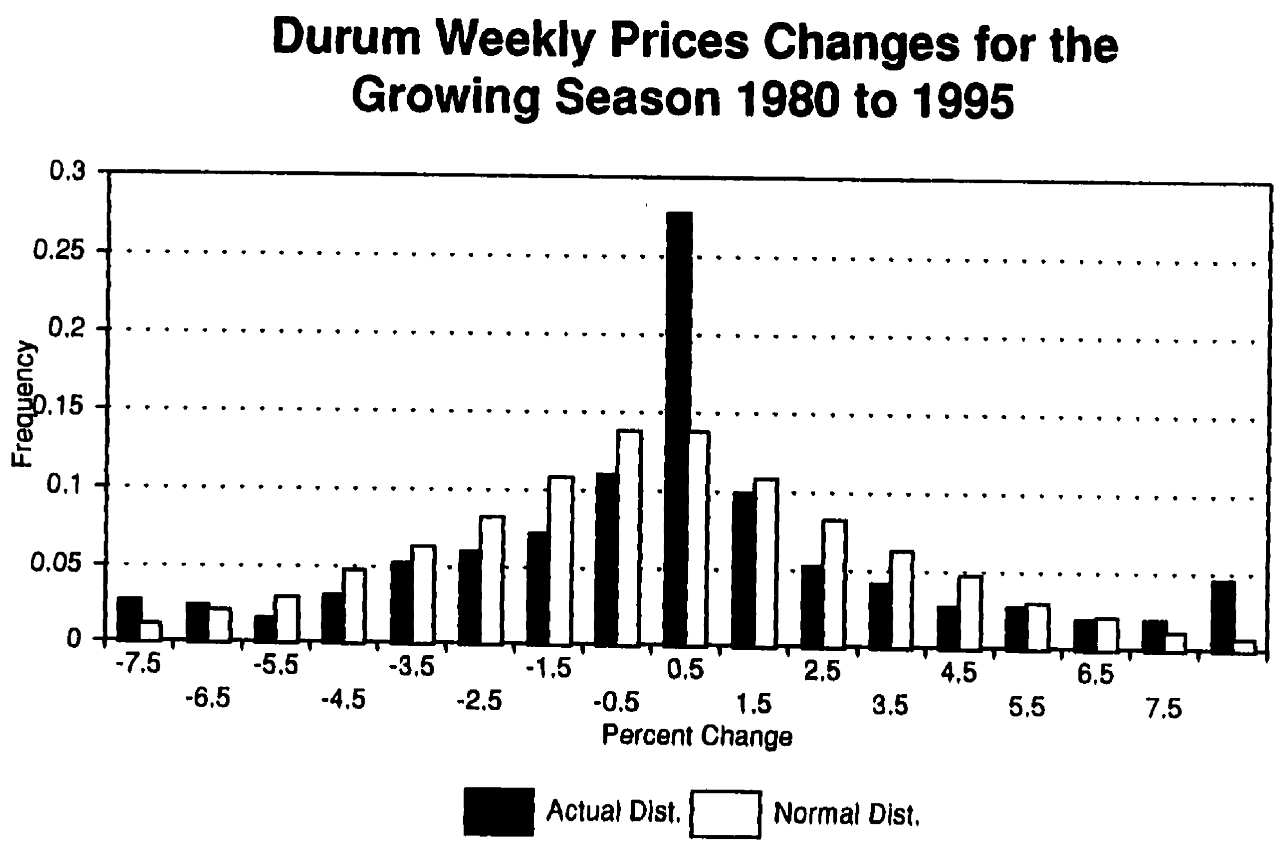
Source: USDA Grain and Feed Market News

Figure 1.2



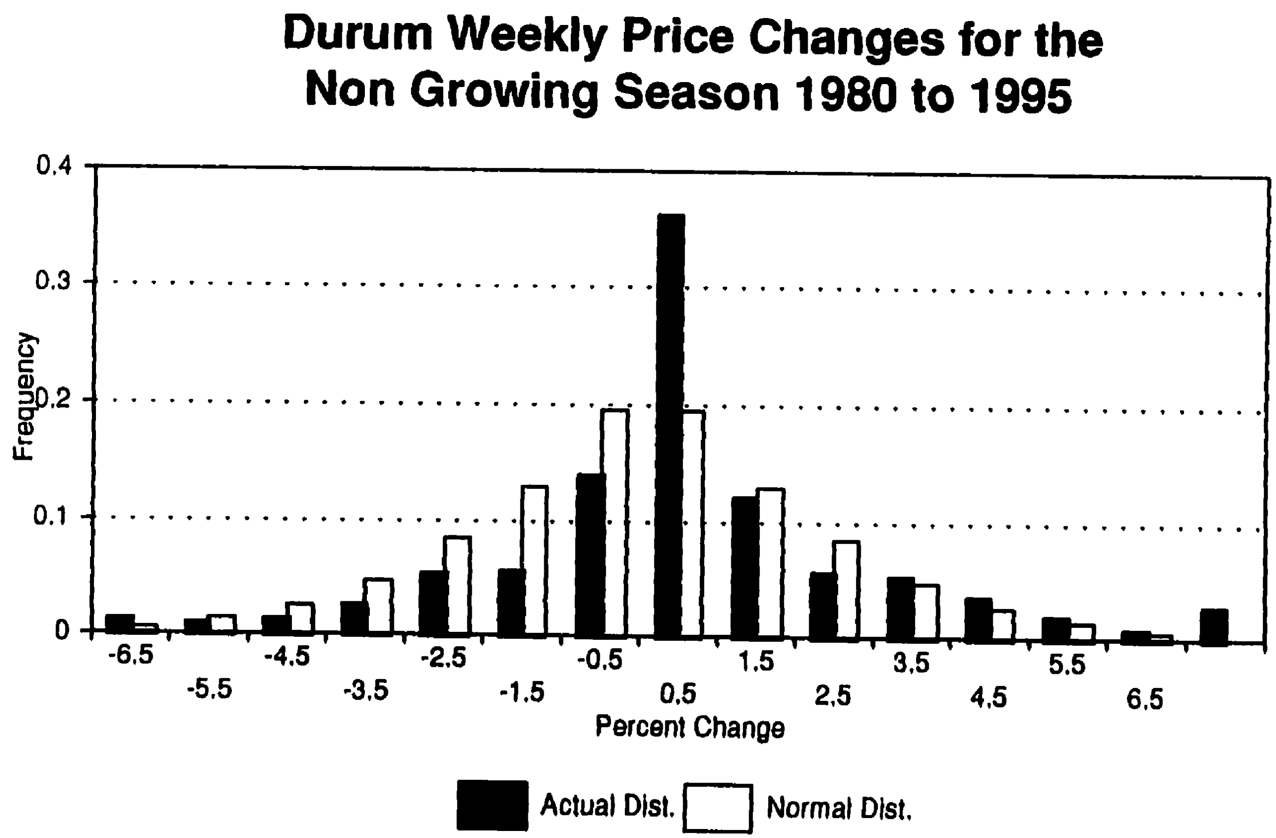
Source: USDA Grain and Feed Market News.

Figure 1.3



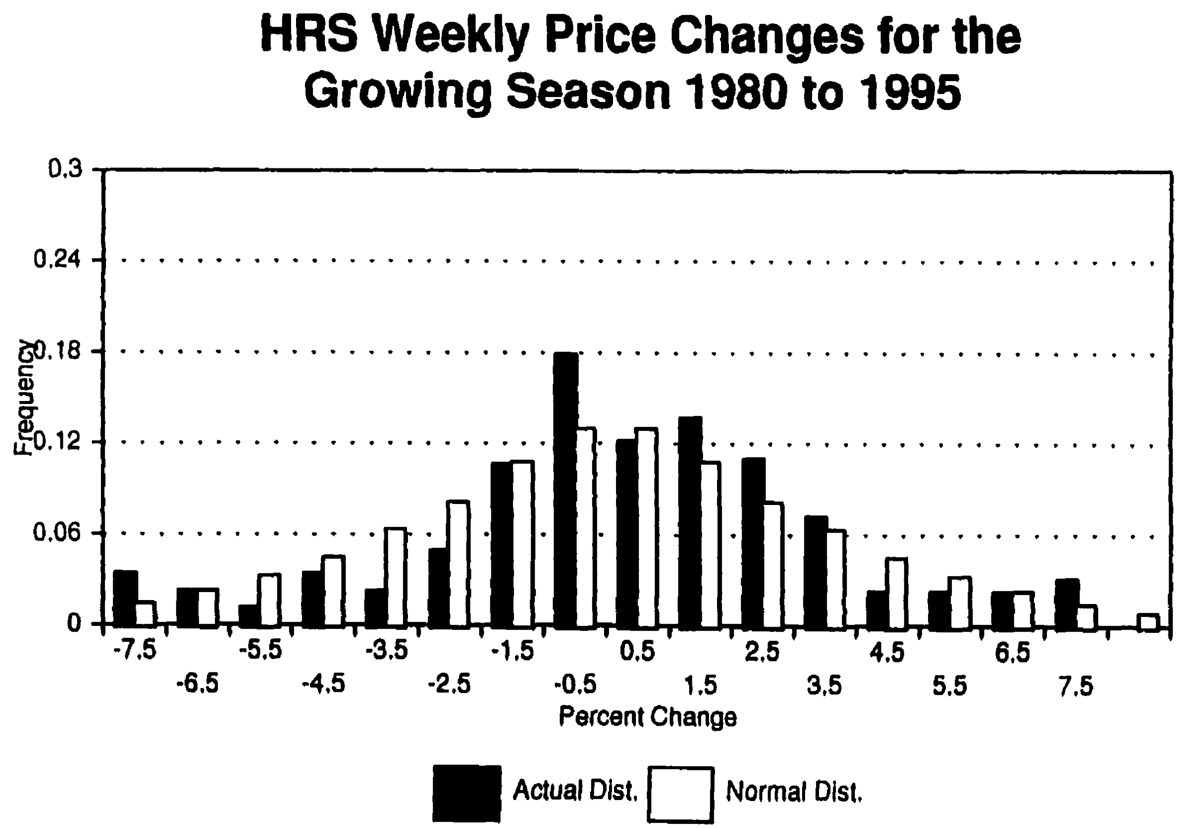
Source: USDA Weekly Grain and Feed Market News.

Figure 1.4



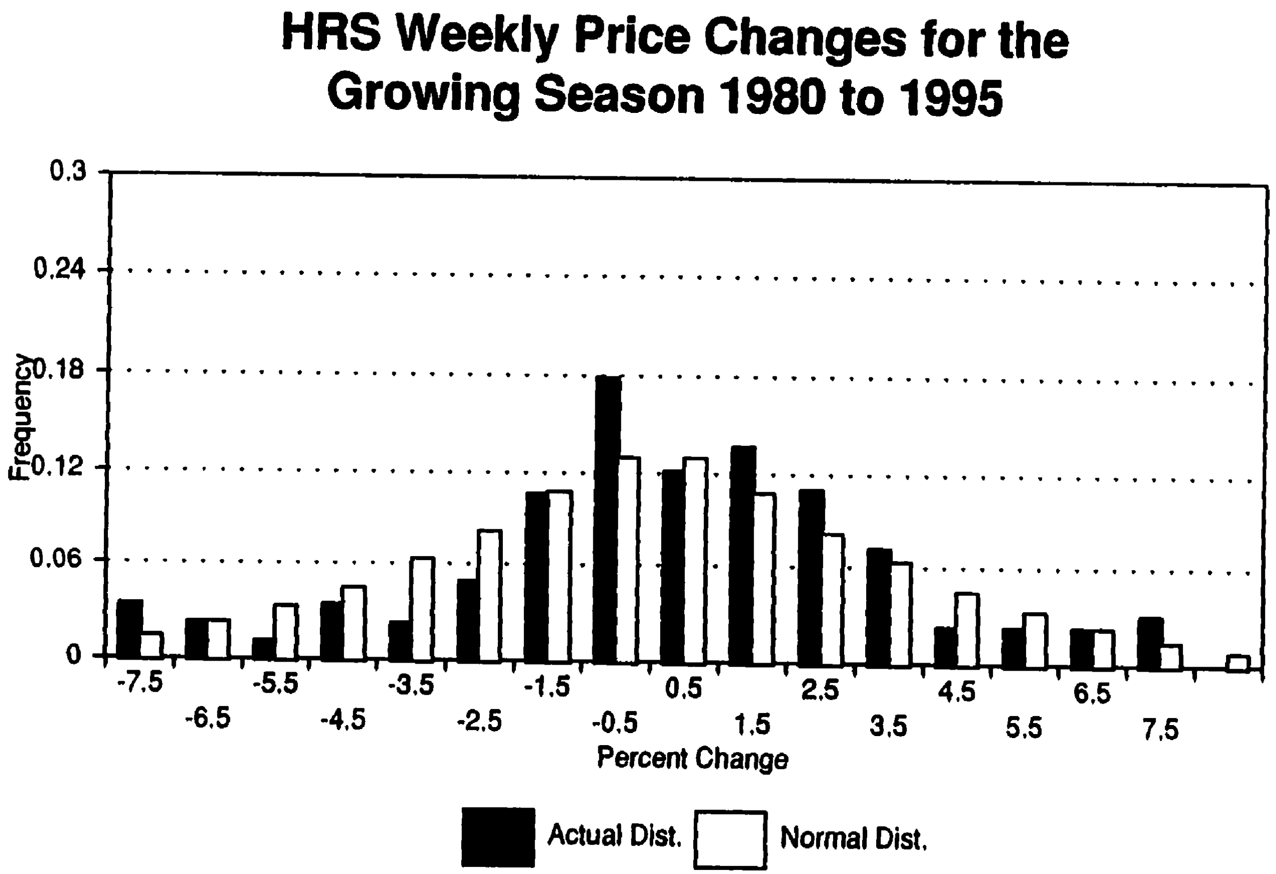
Source: USDA Weekly Grain and Feed Market News.

Figure 1.5



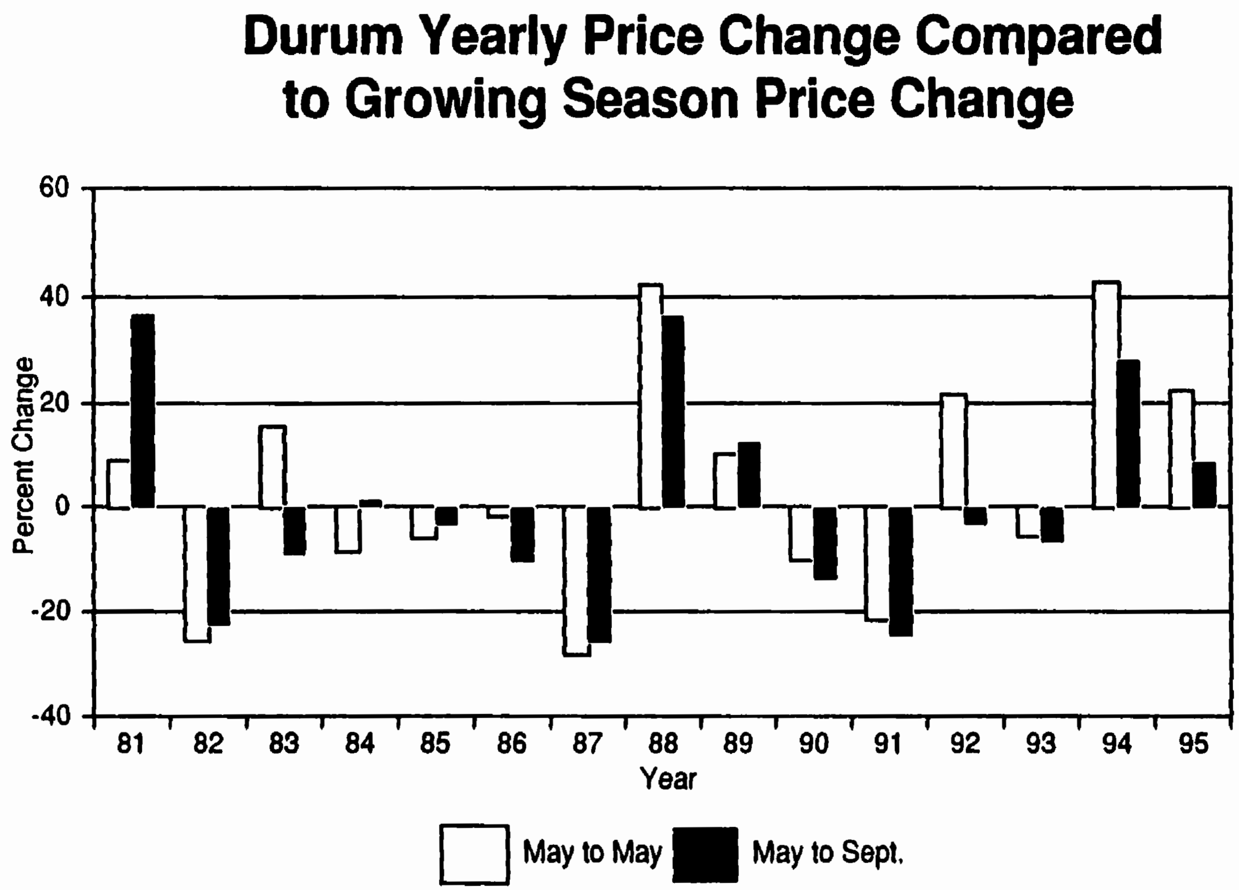
Source: USDA Weekly Grain and Feed Market News.

Figure 1.6



Source: USDA Weekly Grain and Feed Market News.

Figure 1.7



Source: USDA Grain and Feed Market News

Chapter II

Price Forecasts

2.1 Introduction and Naive Model

When entering into a forward contract the risk of price fluctuation is removed for both buyer and seller. However, it is not likely that the price on the delivery date will be the same as the contract price. Therefore one party will incur a loss, based on opportunity. If the seller had some indication of how prices will move between the date that the contract is entered into and the delivery date (about thirteen weeks) they could reduce the risk of an opportunity loss. In this chapter prices are forecast thirteen weeks ahead to indicate what prices will be on the delivery date, if a forward contract entered into during each week of June, July and August, when production is unknown. The forecast price will indicate whether the seller should contract at a premium to the current price or be satisfied contracting at the current price, in order to reduce the risk of an opportunity loss.

In order to isolate the value of using weather information to forecast future prices, a model using only past prices is estimated first. Then a model using past prices and a supply variable, which is estimated using weather information, is compared to the model using only past prices. Any extra forecasting ability of the model with the weather variable can be attributed to the weather information.

A naive model is used to represent the current price as a forecast for the future price. The naive forecast is used as a bench mark for evaluating other forecasting models. The forecasting models that use more information in terms of past prices and weather information would be expected to be an improvement upon the naive model. The naive model is expressed as:

$$\hat{P}_{t+13} = P_t \tag{2.1}$$

where P_{t+13} is the price to be forecast, and P_t is the current price. Thirteen weeks is used to represent the average amount of time it takes to move grain from an elevator on the prairies to the delivery point at a port.

2.2 ARIMA Time Series Model

One approach to building a time-series model is the Box-Jenkins approach of building an Autoregressive Integrated Moving Average model (ARIMA). The basic ARIMA model has the following form:

$$x_t = \alpha_1 + \alpha_1 x_{t-1} + \alpha_2 x_{t-2} + \dots + \alpha_p x_{t-p} + y_t \ , \tag{2.2}$$

where y_t is defined as:

$$y_t = \epsilon_t + B_1 \epsilon_{t-1} + B_2 \epsilon_{t-2} + \dots + B_q \epsilon_{t-q} \qquad \epsilon_t \sim IID(0,\sigma^2) \tag{2.3}$$

This is an autoregressive-moving average process or order (p,q) and is denoted ARMA (p,q). An ARIMA model is simply an ARMA model in which the data has been differenced d times. Differencing is used to achieve stationarity in a time series that is otherwise non-stationary. Thus, an ARIMA model is denoted (p,d,q). Box-Jenkins analysis involves four steps: identification, estimation, diagnostic checking, and finally forecasting with the final model. However before these steps the series must be checked for stationarity because the ARMA process is only valid if the series being modeled is stationary.

The main difference between ARIMA and regression approaches to time series analysis is that regression models are built from theory and prior research and ARIMA models are built from the data. ARIMA models require a relatively long time series because the models are identified from the data being modeled.

There are two reasons why an ARIMA model was not appropriate for forecasting durum prices in this study. The first is that a weekly price series is used, and a thirteen week forecast is required. An ARIMA model forecasts the next period's price, which is one week ahead, then uses the one week forecast to forecast two weeks ahead. This results in a model that is forecasting from its own forecasts, thus the model is unstable. The second reason that an ARIMA model was not appropriate in this case was that only the prices during the growing season are affected by weather events and therefore these are the only prices that are relevant to this study. For this reason a continuous time series could not be used to estimate an ARIMA model. A time series with only growing season prices has large price movement when the growing season ends and a new one begins (Sept. To May). An ARIMA model builds this price movement into the modeling of the time series, which is not appropriate. For these reasons a structural regression model is used to forecast durum cash prices thirteen weeks ahead.

2.3 Market Model

In this study regression models using least squares are used to forecast thirteen weeks ahead. The first model begins using prices from the first week of June (week 23) and earlier to forecast a price for the first week of September (week 36). Each week is numbered such that the first week of January would be week 1 and the last week of the year would be week 52. A second model forecasts a price for the second week in September (week 37), from prices in the second week in June (week 24) and earlier, and so forth. The last model forecasts prices for the end of November from prices up to the end of August. The following equations show the basic form of the forecasting models.

$$\begin{aligned} P_{i,36} &= b_{0,36} + b_{1,36}P_{i,23} + b_{2,36}P_{i,22} + b_{3,36}P_{i,21} + e_{36} \\ P_{i,37} &= b_{0,37} + b_{1,37}P_{i,24} + b_{2,37}P_{i,23} + b_{3,37}P_{i,22} + e_{37} \\ &\vdots \\ P_{i,47} &= b_{0,47} + b_{1,47}P_{i,34} + b_{2,47}P_{i,33} + b_{3,47}P_{i,32} + e_{47} \end{aligned} \tag{2.4}$$

where i = 1 to 15 years.

For each week a different forecasting model is estimated with the number of past prices that generates the lowest residual variance for the model while still providing significant coefficients. Thus forecasts for different weeks are generated from a different number of past prices. These models are referred to as the market models in this study because they only use information from the market to forecast prices.

Serial correlation is often found in models that are estimated using time series data. It exists when successive error terms are correlated with each other. The consequences of estimating a model using OLS when serial correlation exits are parameter estimates that are inefficient and inferences based upon them are invalid. Each model was checked for first order serial correlation using the Durbin-Watson statistic, and corrected if need be using the Cochrane-Orcutt procedure (Davidson and MacKinnon, 1993).

Using data that is stationary is also important when estimating a model using OLS. Detrending a time series is appropriate if it is trend-stationary, otherwise differencing the data may achieve stationarity. For example a time series can be differenced once as follows:

$$Y_t^* = Y_t - Y_{t-1}, \tag{2.5}$$

where Y_t* is the differenced time series. To test for stationarity in the data the augmented Dickey-Fuller unit root tests are performed (Davidson and MacKinnon, 1993). The data was found to be non-stationary and was differenced between years to create a stationary data set. Therefore the price variables for each week represent the change in price from the previous year. Differencing the data once reduces the number of observations in the data set by one observation.

2.4 Weather and Durum Supply Models

2.4.1 Drought Index

In order to incorporate weather information into the forecasting models a weather variable is defined. The basis of the weather variable is a drought index. The drought index forecasts wheat yields from current and past weather and assumes average weather conditions for the unknown weather during the growing season. The model that calculates the drought index is developed in Walker (1989). Since drought is the foremost yield-limiting factor for wheat, the drought index is calculated on a physiological basis using temperature and precipitation data.

The drought index is calculated to reflect the balance between cumulative water supply and transpiration demand. The water supply represents all water available to the crop starting in the preceding summer and taking into consideration evaporation and drainage loss. The crops' demand for water is determined by temperature and phenology. The stress on the crop brought on by drought is as a function of the difference between supply and demand for water. The cumulative difference between supply and demand is then the basis for calculating the drought index. If the difference between supply and demand becomes negative the degree of water stress increases and growth begins to be limited. The drought index is calculated for all weather stations within the wheat production area that have temperature and precipitation data available.

Each station is assigned a weight according to the amount of acreage in the area and then a mean weighted drought index (D) is calculated. Average yields for the region are regressed on D to give a predictive equation. Monthly temperature and precipitation data are input into the model and updated weekly throughout the growing season. At the beginning of the growing season the data consists of long-term averages and as the season progresses the data is updated weekly with actual data.

The drought index in this study is calculated for durum wheat only, and includes both United States and Canadian weather stations. Eight weather stations are used to cover the durum producing areas in both countries. They include Medicine Hat, Swift

Current, Regina and Outlook in Canada and Bottineau, Crosby and Towner in the United States. Figure 2.1 shows the location of these weather stations. For each station a drought index is calculated every week beginning in the first week of June. The drought index for the first week in June uses actual total monthly precipitation starting in April the year before and the actual monthly mean temperature for May of the current year. The weather for June, July and August is unknown so weather data for the previous fifty years is used in place of the unknown weather for the current year. A drought index is calculated using weather data from each of the previous fifty years and then the resulting drought indexes are averaged to give one drought index for the first week of June. As the season progresses actual weather data replaces the historical weather data. However, most weather data is aggregated into monthly variables. Therefore to update the drought index weekly with actual weather data, the monthly precipitation is divided by the number actual days the index is updated by week. For example if the drought index is to be calculated for June 7, then the actual precipitation for that year will be the total precipitation for June multiplied by 7/30. Mean monthly temperature is the same throughout the month. Canadian weather data was obtained from the Canadian Wheat Board's Weather and Crop Surveillance Department. The U.S. weather data was obtained from the National Climate Data Center.

The weighting of the indexes for each station was done first within the countries. In Canada, the prairies are divided up into crop districts for which durum acreage is available. The five weather stations in Canada are assigned the crop districts in the area so that they can be weighted. The weighting is done according to the fifteen year (1980-

1995) average durum acreage for the crop districts corresponding to each weather station. Table 2.1 shows the calculation of the weights for the Canadian weather stations. In the United States most of the durum is produced in North Dakota. North Dakota durum acreage is available by county, so each weather station in North Dakota is weighted according to the fifteen year (1980-1995) average durum acreage for the counties that are assigned to the weather station. Table 2.2 shows the calculation of the weights for the three weather stations in the United States. The weather stations are then weighted according to the amount of production in Canada vs. North Dakota, which results in multiplying the Canadian stations weights in Table 2.1 by .62 and the United States stations weights in Table 2.2 by .38. After all weather station's drought indexes are weighted accordingly, one drought index for the entire North American durum producing area is calculated (see appendix A, Table A.1).

The weighted drought index using all actual weather information is regressed on the weighted actual yields of Canada and the United States to produce a predictive equation. The resulting durum yield predictive equation is shown below:

$$\underset{}{Yield} = \underset{(1.78)}{-15.42} + \underset{(.074)}{.881}\,(DI) \qquad (2.6)$$

where DI is the weighted drought index for Canada and North Dakota. This equation has an R-squared of .91 and is used to forecast durum yields from all of the drought indexes calculated during each growing season from 1980 to 1995. Table 2.3 shows the yield forecasts that are derived from the drought indexes and the standard deviations for each week.

2.4.2 Specification of Supply Variable

(i) Perfect Weather Knowledge

A supply variable that reflects perfect knowledge of weather events for the entire growing season is included in the econometric models to forecast durum prices . Actual production is used in the specification of the supply variable to accomplish this. Actual production is calculated by multiplying the actual Canadian yield by the number of harvested acres in Canada and adding North Dakota production, which is calculated in the same way. The supply variable is specified in the following way:

$$\begin{gathered}(\textit{Actual Production} + \textit{Actual Stocks})_t - \\ (\textit{Actual Production} + \textit{Actual Stocks})_{t-1}\end{gathered} \tag{2.6}$$

where actual stocks are beginning stocks for Canada and the United States for a given year. Specifying the supply variable in this way allows for it to be a negative number if total supply for the current year are less than the previous year. This variable assumes perfect weather knowledge so the variable is constant throughout each year and is referred to as the perfect weather model. This supply variable is added to the market models (eq. 2.4) and the models are re-estimated.

(ii) Current Weather Knowledge

A different supply variable is specified to reflect current weather knowledge throughout the growing season. It is specified in the same way that the perfect weather variable is specified, except that forecast yields are used instead of actual yields in calculating forecasted production. Thus, the supply variable using current weather knowledge is specified as follows:

$$(Forecasted\ Production + Actual\ Stocks)_t - (Actual\ Production + Actual\ Stocks)_{t-1} \tag{2.7}$$

The forecast yields are calculated through the drought index. The drought index changes each week, therefore the supply variable changes each week. This supply variable is substituted in place of the perfect weather knowledge supply variable in the perfect weather model to obtain different price forecasts with a different level of weather knowledge.

(iii) One Week Perfect Weather Knowledge

This specification of the supply variable is done to simulate a one week perfect weather forecast. The supply variable is specified in the same way as the previous supply variable except that the yield forecasts for the next week are used for the current week. For example, the drought index which uses current weather, calculated at June 14 is used in the specification of the supply variable for June 7. Therefore, the supply variable specified on June 7th has perfect knowledge of weather events one week in advance. This supply variable is also substituted in place of the perfect weather knowledge supply variable in the perfect weather model to obtain another price forecast with again another level of weather knowledge.

2.5 Reliability of Forecasts

In the above sections four different price forecasting models are estimated; one without any weather information and three with different levels of weather information.

One way of comparing the reliability of the different models is by calculating the variance of the prices that the different models forecast. The variance of the prices that the market model and the perfect weather model forecasts is calculated as follows:

$$V_p = \left[\bar{X}^T\right] VB \left[\bar{X}\right] + \sigma_e^2 \tag{2.8}$$

where $\bar{X}$ is the vector of past prices and the weather variable used to estimate the price (p) and VB is the covariance matrix of the estimated coefficients. By using matrix multiplication and adding the residual variance (σ_e^2) the variance of each forecasted

price (V_p) is calculated. The residual variance is calculated from each econometric model and is therefore the same for each year within each model.

To calculate the variance of the prices that the weather model and the one week weather model forecasts, a slightly different approach is taken because of the extract uncertainty that the yield forecasts add to the variance. Equation 2.8 is also used in the calculation price variance for these models, except that the following equation is added to it to account for the yield uncertainty:

$$+ \left[\bar{B}^T\right] Vx \left[\bar{B}\right] \tag{2.9}$$

However, if there is only one stochastic variable such as in this case with the yield forecast in the supply variable then equation 2.9 simplifies to $\bar{B}_y^2 V_{x_y}$. Where x_y is the only variable that is stochastic. In this case the variance from the yield forecast is multiplied by the supply variable coefficient squared.

2.6 Summary

In this chapter four different econometric models are developed. The market model uses only past prices to forecast the durum price in thirteen weeks, the perfect weather model uses actual production for each year, in addition to past prices to forecast the price in thirteen weeks. The weather model uses the current weather and a drought index to predict production for each year and then uses the production forecasts in the econometric model to forecast the price in thirteen weeks. The one week perfect weather model uses perfect weather knowledge for one week into the future and the drought index to predict production for each year and then uses the production forecasts in the econometric model. The reliability of the price forecasts from each of the models are evaluated by calculating the variance of each price forecast.

Table 2.1 Calculation of Weights for Canadian Weather Stations (000 Acres)

Province	Crop District	15 Year Ave. Acreage	Acreage Sub-Total	Weighting	Weather Station
Alberta	1	222.4			
	2	328.3			
			550.7	.12	Medicine Hat
Sask.	4	560.4			
	3a	604			
	3b	879.4			
			2043.8	.46	Swift Current
Sask.	2	685			
	5	105.5			
			790.5	.18	Regina
Sask.	6	239.1			
	7	348			
	8	21.8			
	9	19.2			
			628.1	.14	Outlook
Sask.	1	229.2			
Manitoba	1	85.7			
	2	50.8			
	3	25			
	8	47.2			
			438.2	.10	Yellow Grass

Soure: CANSIM

Table 2.2 Calculation of North Dakota Weather Station Weights (000 Acres)

County	15 Year Ave. Acreage	Acreage Sub-Total	Weighting	Weather Station
Divide	178.6			
Williams	140.3			
McKenzie	42.7			
Burke	78.8			
Mountrail	217.3			
		657.7	.27	Crosby
Ward	215.7			
McLean	184.6			
McHenry	29.9			
Pierce	70.3			
Benson	160.6			
Wells	61.8			
Stutsman	71.5			
Ramsey	149.8			
Nelson	79.2			
		1023.2	.42	Towner
Renville	79.1			
Bottineau	200.4			
Rollette	101.1			
Towner	202.6			
Cavalier	137.9			
Walsh	33.0			
		754.0	.31	Bottineau

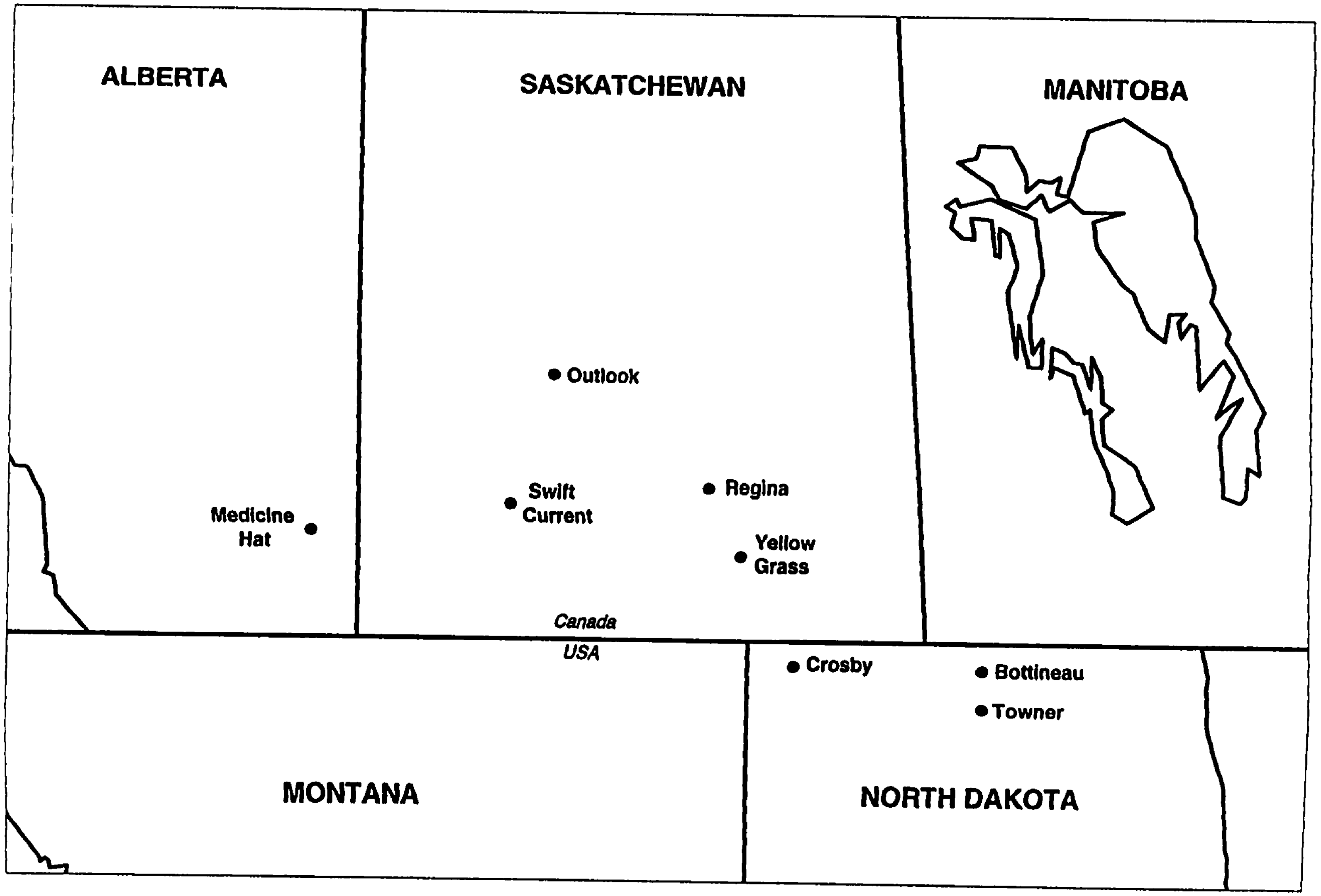
Source: USDA, NASS.

Table 2.3 Actual Yields, Forecast Yields and Standard Deviations by Week (bu/acre)

		Week of the Year					
Year	Actual	23	24	25	26	27	28
1980	21.29	21.68	21.32	20.89	20.41	20.11	19.78
1981	27.14	27.26	27.26	27.89	28.42	28.79	29.05
1982	31.82	28.31	28.31	28.22	28.01	27.59	28.47
1983	27.12	26.99	26.55	26.08	25.52	25.90	26.45
1984	22.49	25.10	24.88	24.58	24.22	23.54	22.67
1985	23.84	26.68	26.5	26.2	25.80	24.16	24.28
1986	31.63	29.42	28.96	28.34	27.62	27.41	27.64
1987	26.81	27.28	27.28	26.39	25.43	24.71	25.42
1988	12.81	22.97	21.35	19.8	18.17	17.49	17.00
1989	22.87	26.23	26.27	26.25	26.15	25.88	25.58
1990	31.40	27.04	26.93	26.74	26.45	25.44	27.88
1991	32.98	30.12	30.92	31.39	31.59	31.72	31.95
1992	34.28	27.88	27.52	27.06	26.51	26.11	27.26
1993	33.29	25.90	26.61	27.23	27.74	31.18	30.34
1994	31.20	31.18	31.66	32.03	32.30	32.33	32.36
1995	29.69	27.87	27.79	27.65	27.50	27.51	27.59
Std		4.10	3.85	3.61	3.45	3.41	2.74

		Week of the Year					
Year	Actual	29	30	31	32	33	34
1980	21.29	20.35	20.49	20.66	20.81	20.96	21.13
1981	27.14	29.26	29.49	29.72	29.56	29.26	29.00
1982	31.82	29.27	30.10	30.94	31.36	31.50	31.65
1983	27.12	27.05	27.57	27.64	27.22	26.84	26.56
1984	22.49	21.85	21.06	20.44	20.27	20.12	19.99
1985	23.84	23.42	22.55	21.77	21.92	22.01	22.29
1986	31.63	29.21	30.18	31.16	31.28	31.26	31.25
1987	26.81	26.16	26.92	27.69	28.04	28.23	28.45
1988	12.81	16.55	16.11	15.86	15.84	15.84	15.83
1989	22.87	25.28	24.98	24.69	24.49	24.30	24.16
1990	31.40	28.95	30.06	31.02	30.88	30.75	30.64
1991	32.98	32.16	32.34	32.46	32.28	32.06	31.86
1992	34.28	28.54	29.88	31.04	31.5	31.79	32.12
1993	33.29	33.13	35.87	36.94	36.88	36.85	36.61
1994	31.20	32.36	32.27	32.14	32.12	32.09	32.08
1995	29.69	27.66	27.74	27.78	27.70	27.63	27.57
Std		2.21	1.99	1.92	1.84	1.81	1.75

Figure 2.1 Map of Weather Stations



Chapter III

Decision Analysis Model

3.1 Introduction

In this chapter decision analysis models are used to determine the optimal amount of durum wheat to forward sell. From the price forecasts in chapter two, the decision maker has an idea of what direction the price of durum is likely to move. Now the decision maker must decide how much durum to forward sell, given the price forecasts. Four different decision models are specified which correspond with the four different price forecasting models in chapter two. They are: the market model, perfect weather model, current weather model and one week perfect weather model.

3.2 Decision Analysis Theory

Decision analysis is the study of how people make decisions, particularly when faced with imperfect information. It includes a collection of techniques to support the analysis of decision problems (Camm and Evans, 1995). Decision analysis can be used to assist the decision maker when faced with several different alternatives and uncertainty about future events. Its purpose is to provide information about the likelihood of different occurrences to enable the decision maker to identify the best course of action. This is done by modeling the decision making process in which a number of decision alternatives are available to the decision maker (Anderson et al. 1991).

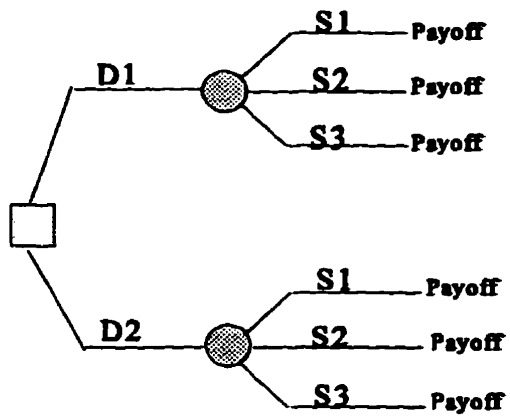
The first step of decision analysis is to identify the decision alternatives. These decision alternatives represent the choices the decision maker can make. For example, when deciding to forward contract durum there are several possible decision alternatives, such as forward selling above or below average quantities of durum normally sold during a certain week. The best decision alternative depends on what happens to durum prices after the forward contract has been signed or deferred However, future durum prices are uncertain so the best decision is not known with certainty.

Choosing the best decision alternative often depends on the outcome of uncertain future events associated with the decision. The decision maker may have an idea of possible future events, but is uncertain about which event will actually occur. The second step of decision analysis is to define the future events that may occur once a decision is made. These future events are referred to as the states of nature, which reflects the fact that the decision maker does not have control over them. These states of nature provide the basis for evaluating risks associated with the decisions.

3.2.1 Decision Trees

A decision tree is a graphical representation of the decision-making process. Figure 3.1 shows a decision tree with two decisions and three states of nature. The tree is read from left to right to show the logical progression that will occur over time. First the decision maker must choose between D1 and D2, which could be forward price 20 thousand tonnes or wait and price 20 thousand tonnes of durum at the time of delivery. Once the decision is made, the decision maker observes what state of nature occurs. For each decision, each of the three states of nature may occur, which could be that the price of durum increases, remains the same or falls by the time the delivery to the buyer occurs. At each end point of the tree there is a payoff which is associated with a particular chain of events. Each possible sequence of events is represented in a decision tree.

Figure 3.1 Decision Tree



A decision tree consists of decision nodes, which are represented by squares. The lines which stem from the decision nodes are referred to as decision branches. Each decision alternative is represented by a decision branch in the decision tree. The circles in the decision tree are state of nature nodes and the lines stemming from them are referred to as states of nature branches.

3.2.2 Decision Making Under Risk

Risk exists when perfect information is not available, but the probabilities that certain outcomes will occur can be estimated. When it is possible to estimate probabilities for each state of nature the expected value approach can be used to select the best decision alternative. Each decision alternative is evaluated in terms of expected value. The decision alternative with the highest expected value is selected as the optimal decision. The expected value of a decision alternative is the sum of payoffs for the decision, weighted by the probability of the associated states of nature. The expected value (EV) of decision alternative d_i is defined as follows:

$$EV(d_i) = \sum_{j=1}^{N} P(s_j)V(d_i, s_j)$$

where, N = the number of states of nature, $P(s_j)$ = the probability of state of nature s_j occurring, and $V(d_i,s_j)$ is the payoff associated with d_i, if state of nature s_j occurs.

A decision tree provides a convenient way to perform the calculations needed to identify the optimal decision alternative. By working backwards through the decision tree, the expected payoff is calculated at each state of nature node first. This is done by multiplying the values at the end of the states of nature branches by their associated probabilities and summing. In other words, each payoff is weighted by its chance of occurrence. Then, moving to the left of the tree the decision alternative with the highest EV is selected as the optimal decision.

3.2.3 Decision Analysis with Sample Information

Acquiring additional information about possible future events improves the current probability assessment for the states of nature. Additional information can be acquired through experiments designed to provide sample information. Market research and product testing are examples of this type of sample information. However, information is not free, so the decision maker must decide whether the information is worth the cost of acquiring it. That is, whether the information has ability to alter decisions and therefore increase the decision maker's expected value, by at least the cost of the information. This is evaluated by revising the initial probabilities assigned to the states of nature with the sample information and then using the revised probabilities to develop another optimal decision strategy.

The initial probabilities assigned to the states of nature are referred to as prior probabilities to reflect the fact that they are determined prior to acquiring any additional information and are denoted as $P(s_j)$. Additional information is combined with the prior probabilities through a Bayesian procedure to obtain updated or revised probabilities. New information is referred to as an indicator or sample information. If the sample information was a forecasting model for durum prices it could be denoted as follows:

I_1 = Price Increase
I_2 = No Price Change
I_3 = Price Decrease

The purpose of indicators is to improve probability estimates of the states of nature so that the posterior probabilities reflect the indicator information. Posterior probabilities are denoted as $P(s_j|I_k)$, which is a conditional probability that the state of nature s_j will occur given the indicator I_k. In order to calculate the posterior probabilities the reliability of the indicator must be quantified first. This can be done by evaluating past results of the sample information to find the relationship between the indicator and the states of nature. The probabilities that result from this relationship are called conditional probabilities and are written as $P(I_k|s_j)$, which means the probability that the sample information will predict

I_k, given state of nature s_j. Conditional probabilities for all indicators, given all states of nature are required to revise the prior probabilities.

The conditional probabilities are first used to calculate indicator probabilities. When an indicator is used, branches are added to the left of the decision tree which are called indicator branches. These branches show the possible outcomes of the sample information ($I_1 ... I_k$). A probability for each indicator branch is calculated using the conditional probabilities and the prior probabilities. The formula to calculate indicator probabilities is:

$$P(I_k) = P(I_k \cap s_1) + P(I_k \cap s_2) + ... + P(I_k \cap s_j) \qquad 3.1$$

which is the sum of all the possible ways in which I_k can occur. $P(I_k \cap s_j)$ is the probability that I_k is predicted and s_j occurs and is calculated as follows:

$$\begin{aligned} P(I_k \cap s_1) &= P(I_k | s_1) P(s_1) \\ P(I_k \cap s_2) &= P(I_k | s_2) P(s_2) \\ &\vdots \\ P(I_k \cap s_j) &= P(I_k | s_j) P(s_j) \end{aligned} \qquad 3.2$$

Once the indicator probabilities are known the Bayesian process can be used to compute the posterior states of nature probabilities:

$$P(s_j | I_k) = \frac{P(I_k \cap s_j)}{P(I_k)} \qquad 3.3$$

The posterior probabilities are then multiplied by the payoffs for their respective state of nature and summed for each decision alternative to give an expected value. The decision alternative with the highest expected value is the optimal decision.

3.3 Specification of Decision Alternatives

3.3.1 Market Model

The market model, as referred to in chapter 2, incorporates only price information from the durum market. The basic decision is how much Canadian durum should be sold under forward contract. Therefore expected production, is assessed to be the product of the 15 year Canadian moving average yield and the current seeded area. However, long term expected production is not a good indication of actual production during years of drought or high yielding years, but this cannot be identified if weather information is not used during the period of forward contracting. Over selling through a forward contract is always a risk if the outcome of the harvest is uncertain. It is an even greater risk though, if the decision maker is allowed to sell a large portion of expected production and expected production over estimates actual production, such as the case of drought years. Therefore the decisions assessed to be available in this model do not include forward selling extreme quantities of expected production to minimize the risk of over selling.

In order to compare this model with other models the quantity of exports each week is held constant for each model. The total quantity of durum that will be exported each week of each year is calculated first by finding the average percentage of exports that was exported during each week between September to mid November (when delivery of the forward contracts will be made) over the period 1980 to 1995. The export percentages for each week are averaged across the weeks to determine the average percent of total durum that is normally exported during a given week between September and the middle of November. The average amount was calculated to be 2.2% of actual production (assuming all durum produced is exported). Actual production is not known at the time of forward contracting so expected production can be used, but should not be more than 2.2% of actual production so that the same quantity is exported each week.

Two decision alternatives are specified for the market model. One is to forward contract half of durum exports for a week and defer pricing the remaining portion until delivery in the thirteenth week. This means forward contracting 1.1% of expected production and deferring the remaining portion of the 2.2% of actual production until the time of export (thirteen weeks). The quantity forward contracted and the quantity that is deferred must always sum to 2.2% of actual production. Therefore forward selling more during the growing season means less will be priced at the time of export. The other decision available is to defer pricing all the durum (2.2% of actual production) for thirteen weeks when it is exported.

Deciding what price to forward contract at is also part of the decision to forward contract. If the decision maker is expecting the price to rise significantly he would not be satisfied contracting at the current price. So the pricing of the forward contracts for the market model depends on what the market price forecasting model is predicting. If the forecasting model is predicting a decrease in price, which is defined as a 7% or greater decrease from the present price, the decision maker would be satisfied with the current price. If the forecasting model is predicting the price change to be less than 7%, then the contract price will include a thirteen week carrying charge (Table 3.1) added to the current price. If the forecasting model is predicting a price increase which exceeds 7%, then the contract price is assumed to be the greater of the current price plus a carrying charge or the current price plus a premium of half the forecasted increase. The contract price is always less than the Canadian Wheat Board's asking price for that week to reduce the possibility that the contract price would alter the market price in the future. This is possible because the CWB controls a large enough portion of the durum market that it could affect the market price if the model suggested that it be contracted above the previous asking price.

3.3.2 Perfect Weather Model

The perfect weather model assumes that weather for the entire growing season is known and therefore actual production is known throughout the growing season. This information is used in determining the optimal quantity of durum to forward contract. In this model, unlike the market model, the risk of over selling in a forward contract is reduced greatly. This makes it possible for decisions that allow forward contracting more extreme quantities than the market model allows, but with low risk of over selling still. The total quantity that is exported each week is the same as the market model to allow for comparisons (2.2% of actual production).

The perfect weather model allows for three decisions, which all involve some level of forwarding contracting. One decision alternative is to forward contract 1.1% of actual production, which is half of the exports for each week, and defer pricing the other 1.1% of actual production for thirteen weeks when the durum is delivered. The other two decision alternatives include forward selling either 80% or 20% of durum exports for each week, and deferring pricing either 20% or 80% respectively for thirteen weeks when delivery is made. In terms of production this means that either 1.76% of actual production is forward sold or .44% of actual production is forward sold. The forward contract price is determined in the same way that it is for the market model.

3.3.3 Current and One Week Perfect Weather Models

Both the current weather model and the one week perfect weather model include weather information that is based on the drought index discussed in chapter 2. The current weather model uses known weather to date, expected precipitation and temperatures for the remainder of the growing season to forecast production. The one week perfect weather model uses actual weather events up to the current week, a perfect weather forecast for the following week and expected weather for the remainder of the growing season. This information is used in the pricing model to revise expected prices and determine the optimal quantity of durum to forward contract each week. The weather information should reduce the risk of over selling in a forward contract. The total quantity exported each week is the same as the previous models to allow for comparisons (2.2% of actual production).

The decisions alternatives for these two models are the same as the perfect weather model's decision alternatives, except that actual production is not known in these models. However, Canadian production can be forecasted using the drought index for Canadian. The drought index that was used to forecast prices included North Dakota, so the weather stations in North Dakota are removed to calculate an all Canadian drought index. Then the Canadian drought index is regressed on actual Canadian yields to get the equation that will forecast yields for Canada from the Canadian drought index.

One of the decision alternatives is to forward contract 1.1% of forecasted production and defer pricing the remaining portion of 2.2% of actual production for thirteen weeks. The other two decisions are to forward contract either 80% or 20% of forecasted production and defer pricing the remaining portion of 2.2% of actual production for thirteen weeks. Forecasted production for the current weather model is different from forecasted production for the one week perfect weather model so although they are the same decisions they represent different quantities in the separate models. The forward contract price is determined in the same way as the previous models.

3.4 States of Nature

The states of nature are possible future events that affect the outcome or the payoff of the decision alternatives. The states of nature are the same for all four of the models. Three states of a nature are defined, and denoted as:

$$s_i = \text{price increase}$$
$$s_{nc} = \text{no change in price}$$
$$s_d = \text{price decrease}$$

A price increase is defined as an increase of at least 7%, a price decrease is defined as a decrease of at least 7% and no change in the price is defined as an increase or decrease that is less than 7%.

3.5 Probabilities

3.5.1 Prior Probabilities

The prior probabilities are the probabilities that each state of nature will occur. For the four models being studied here the prior probabilities are the probabilities that the price will increase, decrease or not change. The prior probabilities are calculated by adding or subtracting 7% from the current price and then finding the probability that the price in 13 weeks will be greater than the current price plus 7% and the probability that the price in 13 weeks will be less than the current price minus 7% under a normal distribution. The standard deviation of the price forecasts which has been calculated in chapter 2, is the standard deviation of the normal distribution and the price forecast is the mean of the normal distribution. The probability that the price in 13 weeks will not have changed is calculated by subtracting the probabilities that the price will increase and decrease from one. Prior probabilities are calculated in this way for all four models.

3.5.2 Conditional Probabilities

Conditional probabilities show the relationship between the indicator and the states of nature or in other words they show the reliability of the indicator. These probabilities are used to revise the prior probabilities and calculate the posterior probabilities. The indicator for each model is determined from the corresponding econometric model specified in chapter 2. The indicators predict whether the price increases, decreases or does not change. Conditional probabilities are calculated by summing the number of times that the actual price increased, decreased or did not change over each 12 week interval, starting in the first week of June from 1980 to 1994. The number of price increases, decreases and no changes that the econometric models forecast are summed, given that one of the states of nature occurred, for example the number of price increases forecast by a specific model when a price increase actually occurred. This number is divided by the total number of actual price increases to calculate the conditional probability of the econometric model predicting a price increase given that a price increase actually occurred, which is denoted as $P(I_i|s_i)$. Conditional probabilities are calculated in this way for all four econometric models and are given in Table 3.2. The number of actual price increases, decreases and no changes that the conditional probabilities are calculated from are: 62 increases, 89 no changes, 29 decreases.

The conditional probabilities for each of the models in Table 3.2 indicate that when a forecasted price increase exceeded 7% of the current price the resulting realized price had in fact increased by more than 7% three out of four times. About one out of four predictions of a price increase exceeding 7% resulted in no change in price. The models predicted a price increase exceeding 7% in one out of twelve forecasts when in fact they fell by more than 7%. In the instances when the prices actually decreased when forecast to increase a sales program where less durum is contracted at the current price will show high opportunity cost as the best contract would be to forward contract. Therefore, the conditional probabilities in the case of forecasting rising prices were not infallible.

When the models forecast that prices are unlikely to change they were correct half the time and when they were wrong the price tended to decrease more often than it increased. Whether the decision analysis would recommend more or less durum to be contracted through forward sales will depend upon the prior probabilities for each week and posterior probabilities on the amount of grain to be sold. A forecasted decrease in price would in all likelihood result in a decision where more durum would be forward sold at current prices, given that the models were right about half the time, and when the forecasts were incorrect the price did not change a third of the time and never increased. Given the performance of the models it is reasonable to expect that when a decrease was forecasted the most likely decision would be to forward contract sales.

3.5.3 Posterior Probabilities

Posterior probabilities are the probabilities that each state of nature will occur, given the forecast from the econometric model (the indicator). They are calculated using the Bayesian process which is given in equation 3.3. First the branch probabilities are calculated, which are the probabilities that the econometric model will forecast a certain state of nature (equation 3.1, 3.2). Then equation 3.3 is used to calculate posterior probabilities for each of the three decision alternatives given each of the three state of nature. Therefore there are nine posterior probabilities for each possible forecast from the econometric model. Each weather model and the market model use this procedure to calculate their posterior probabilities.

3.6 Choosing the Optimal Decision Alternative

The optimal decision alternative is chosen by picking the decision with the highest expected value. The expected value of the decision alternatives is calculated by multiplying the posterior probability for given state of nature by the payoff for that state of nature. The expected values for the states of nature are summed for each decision alternative and then the decision alternative with the highest expected value is chosen as the optimal decision for that week. The payoff for each state of nature is calculated as the revenue from the sale of 2.2% of actual durum production. However, some of the durum is forward contracted and some is not priced for 13 weeks when one of the states of nature occurs. To calculate the expected payoff from each state of nature we must have some indication of what the price will be if it increases and if it decreases. Therefore the average price increase and decrease for the 12 weeks being studied from 1980 to 1994 is calculated and used to estimate the price of durum if each state of nature were to occur. The average price increase for this period is 21.7% and the average price decrease is 12.2%. So when calculating the expected payoff for the price increase state of nature, the portion of durum that is priced when the state of nature occurs is priced at the current price plus 21.7%. For the price decrease state of nature the portion of durum that is priced when the state of nature occurs is priced at the current price minus 12.2% and for the no change in price state of nature the current price is used. The optimal decision alternative for each model is chosen in the same way.

Once the decision alternative with the highest expected value is chosen for each model then that decision is evaluated in terms of what actually happened to the price in thirteen weeks. The actual price is used to calculate the revenue from the durum that was price deferred and the revenue from the forward contract is added to find a total revenue. These revenues are compared between models to find which model produced the most revenue for the decision maker for each week from 1980 to 1995.

3.7 Summary

In this chapter, four decision models are developed to find the optimal amount of durum to forward contract. There are three different quantities of durum that can be forward sold in the weather models and only one in the market model. However, the same amount of durum is exported each week so forward selling more during the growing season means that less will be priced at the time of export and vice versa. The expected value approach is used to determine which quantity of durum should be forward sold. The econometric models in chapter 2 are used as sample information and the accuracy of the forecasts are used to determine the probabilities that the price of durum will increase, decrease or not change. The decision with the highest expected value is chosen as the optimal decision for each model and then the outcomes of these decisions are compared between models to see if the weather information has increased the revenue from durum sales.

Table 3.1 Grain Storage Costs and Carrying Costs for 13 Weeks

Year	Storage Costs (CD$/Tonne)	Carrying Costs (CD$/Tonne)	Total (US$/Tonne)	Total (US cents/bu)
1980	1.84	5.27	6.18	17
1981	1.53	7.52	7.52	20
1982	2.11	7.13	7.25	20
1983	2.04	5.01	5.73	16
1984	2.47	4.09	5.04	14
1985	2.62	4.77	5.41	15
1986	2.43	3.97	4.61	13
1987	2.16	2.48	3.47	9
1988	2.72	2.65	4.41	12
1989	2.29	4.42	5.60	15
1990	3.08	5.16	7.03	19
1991	3.07	3.58	5.81	16
1992	3.17	1.77	4.13	11
1993	3.70	1.57	4.12	11
1994	2.89	1.45	3.14	9

Source: CGC, Weekly Grain Statistics and Historical Tariffs and Fees; Grain Transportation Agency, Rail Rates; CWB, Annual Reports; Bank of Canada Review

Table 3.2 Conditional Probabilities

Market Model

	Model Prediction		
States of Nature	Increase	No Change	Decrease
Increase	.726	.274	0
No Change	.236	.562	.202
Decrease	.138	.414	.448

Perfect Weather Model

	Model Prediction		
States of Nature	Increase	No Change	Decrease
Increase	.742	.258	0
No Change	.337	.506	.157
Decrease	.138	.276	.586

Current Weather Model

	Model Prediction		
States of Nature	Increase	No Change	Decrease
Increase	.774	.226	0
No Change	.326	.506	.169
Decrease	.138	.345	.517

One Week Perfect Weather Model

	Model Prediction		
States of Nature	Increase	No Change	Decrease
Increase	.750	.250	0
No Change	.325	.494	.181
Decrease	.115	.346	.538

Chapter IV

Results

4.1 Price Forecasts

4.1.1 Parameter Estimation

In this chapter, the parameters estimated for the market model and the perfect weather models are reported. Both models consist of twelve equations, each forecasting the durum cash price for a different time interval. The models begin by forecasting the durum cash price for the first week in September (week 36) from information available in June (week 23) and end by forecasting the durum cash price for late November (week 47) from information known in August (week 34). The market model forecasts the durum price thirteen weeks ahead from past prices only. The perfect weather model forecasts the durum price thirteen weeks ahead from past prices and the post harvest durum supply. Both models use Wednesday Minneapolis cash durum prices as reported by the U.S.D.A. Grain and Market News from 1979 to 1995.

The key price relationship underpinning the models is that the year to year changes known prior to harvest will be instrumental in forecasting weekly durum prices in September, October and November. Factors such as a change in durum exports which are known or anticipated in the spring and summer weeks are assumed to be reflected in the weekly prices negotiated in June, July and August, and the post harvest prices will continue to reflect these circumstances. Yearly variability of durum prices shown in

Figure 4.1 indicates variation is lowest in the spring (weeks 19 to 25), highest in the summer (weeks 26 to 39), and less again in the fall (weeks 40 to 47). During the spring when there was uncertainty about the post harvest durum supply, weekly prices of durum were on average about 75 cents per bushel above or below what they were last year at the same time. In the summer the prices averaged close to $1.00 per bushel more or less than the previous year. By fall the year to year variation dropped to 85 cents per bushel. Higher year to year price variation in the summer months is believed to be associated with uncertainty about the upcoming harvest. However, the key relationship underpinning the market and perfect weather models is whether year over year price change which occurs in the spring and summer weeks continues in the post harvest period.

The results of the parameter estimation for the twelve market equations are shown in Table 4.1. The dependent variable in each weekly equation measures how much the current price during late summer and fall changed relative to the same time period in the previous year. For example, in week 37 (mid September) the price between 1980 and 1981 fell $2.50 per bushel from $7.00 per bushel to $4.50 per bushel. The market equation for week 37 is the relationship between this annual post harvest price change and the annual price changes known at least 13 weeks prior to week 37. The independent variable in each market model measures the change in durum prices from one year to the next that occurred in the same week during the spring and summer. For example the price change in week 22 (normally the last week in May) between 1980 and 1981 fell by $0.45 per bushel from $5.50 per bushel to $5.05 per bushel. In other words the market model is founded on the premise that the factors influencing the year to year price changes identified in the spring and summer will be instrumental in determining how much the durum prices will increase or decrease from one year to the next during the weeks afer harvest.

Table 4.1 shows the twelve weekly price equations (week 36 to week 47) have at least two of the independent variables which show a significant statistical relationship with the change in prices in the fall. For example the equation estimated for week 36 incorporates past prices from weeks 23, 22, 21 and 19. Each parameter shows the effect that a cent a bushel change during the spring and summer weeks has on prices in the fall. For example, a one cent price increase in week 23 relative to last year will increase the durum price in week 36 by 87 cents per bushel in the current year over what it was last year. In other words, if the only price change in weeks 19, 21, 22, 23 relative to the previous year was a 10 cent a bushel increase in week 23 then the price in week 36 is expected to be 8.7 cents per bushel higher than last year. The durum market rarely shows an annual price change in one week and not in the others. Normally the current prices are all above or below last years' prices. Therefore, normally all the parameters estimated for the price equations should be taken into account when forecasting a price change. The market model equation that forecasts prices in weeks 36 and 37 identifies four lagged price variables which have a statistically significant relationship with post harvest prices, weeks 39, 42, and 46 have three variables and weeks 38, 40, 41, 43, 44, 45, and 47 two variables. The combined effect of a year over year price change of a cent a bushel for each of the spring and summer weeks requires adding the estimated parameters. Table 4.1 shows that a one cent price increase recorded in weeks 19, 21, 22 and 23 in the model for week 36 will have a combined effect of increasing the price in week 36 by 0.67 cents (0.87-3.24+4.72-1.68). If the durum market is consistently higher by 10 cents per bushel between weeks 19 and 23 over last years' price the market model suggests the price will be 6.7 cents per bushel higher in week 36 relative to the previous year.

The combined effects of a 10 cent a bushel increase (decrease) during the spring and summer on the fall durum prices appears in Table 4.2. None of the weekly models parameters indicate that the fall price of durum is expected to change more than that recorded during the spring and summer months. For each model a 10 cent per bushel change in the spring and summer over the previous year is expected to show between a 6.1 cents per bushel change (week 47) to 9.0 cents per bushel change (week 44).

The results of the parameter estimation for the perfect weather model are shown in Table 4.3. Each week is estimated in the same way that the market model was, using the combination of price changes in spring and summer together with the change in the post harvest durum supply from one year to the next. The number of past prices used in the model estimation ranges from two to four. The change in the durum supply variable was inversely related to the change in post harvest prices. If the quantity of durum increased between years post harvest prices fell, while a drop in durum supplies relative to the previous fall increased prices. The change in durum supplies had the most pronounced price impact in weeks 36 and 37, the first two weeks in September. Aside from the supply of durum the perfect weather model for weeks 36 and 37 is based upon prices in late May and early June. Normally this is during or shortly after the crop is planted and the durum prices known at the time are unable to reflect expected growing conditions. The inclusion of the after harvest supply of durum explains some of the price variation recorded in September that could not be explained by just the change in spring prices. However, the relative importance of knowing the year to year change in the post harvest supply is much less important in explaining the prices from mid September to November. For many of the perfect weather equations, namely for weeks 38 through 47, the change in the available durum supply does not significantly account for the post harvest price changes. The perfect weather model suggests that by mid June the ability to forecast Canadian and North Dakota production with complete certainty would not substantially improve forecasting what the durum prices will be in 13 weeks. The models specified to account for the year to year price changes from mid September throughout the fall suggests that the durum cash markets from mid June to August have already captured many of the primary factors that will be reflected in the prices negotiated in the fall. Durum prices established between 13 and 16 weeks prior to mid September through November suggest that the relative importance of the North American harvest is already reflected in the prices being negotiated in the cash market. For some of the years, especially those when supplies were expected to be adequate to meet expected sales, the change in North American supply would be less important in determining post harvest prices. Similarly the changes in the anticipated quantities demanded by importers, which may be apparent by July and August, are already reflected in the cash market.

The relative importance of a year to year change in spring and summer prices and available durum supplies on the change in fall prices is presented in Table 4.4. For example the week 37 price is forecasted to increase by 4.4 cents per bushel if the prices in weeks 22, 21 and 19 are 10 cents higher than in the previous year. A similar increase in price would be expected to occur if the post harvest durum supplies in North America dropped by 100,000 tonnes. Figure 4.1 shows that over the 16 years included in the study the absolute average year to year change in prices for weeks 22, 21 and 19 was 68 cents per bushel. The absolute annual change in supply was 12 hundred thousand tonnes. In other words, in a typical year the latter May and early June prices changed by 68 cents per bushel relative to last year and they were estimated to account for a September price change of 30 cents per bushel. The remaining September price variation was 55 cents per bushel and accounted for by the change in durum supplies. By early summer, in week 29 the absolute average annual price change for weeks 29, 28 and 27 was 96 cents per bushel. The weather equation price forecast for week 42 estimates the average summer price change will account for a 77 cents per bushel price increase or decrease in the fall. At the same time in week 42 the average change in post harvest supply of durum of 12 hundred thousand tonnes only caused prices to change 23 cents per bushel. Therefore when the prices in week 42 changed by 100 cents per bushel and 77 cents per bushel was due to preceding summer price changes and 23 cents per bushel was due to a change in post harvest North American durum supplies. Once growing conditions were known to buyers and sellers the summer prices became a better indicator of fall prices and the fall prices were affected less by the post harvest supplies.

Therefore technical improvements in the drought index and weather forecasting technology that would improve the durum supply forecasts would not significantly improve durum price forecasts during the fall. By late spring the durum market already reflects the North American supply information that will affect post harvest prices. The durum market is efficient in the sense that it reflects publically available information. The variation in fall durum prices that cannot be explained by spring and summer price changes or changes in North American durum supply may be explained by the change in North Africa's import demand for durum which is known in the spring.

4.1.2 Price Forecasts

Thirteen week price forecasts are generated from the estimated parameters for all four models. The forecasts are generated for the twelve weeks between September and November from 1980 to 1995. Table 4.5 shows the durum prices that the models forecasted for each week. It also shows the actual price at the time of the forecast and the actual price thirteen weeks after the time of the forecast. Prices are given in US cents per bushel.

Table 4.5 does not clearly distinguish one model as being generally the 'best' forecaster ('best' meaning having the smallest error). The perfect weather forecasting model generated the best forecast for week 36 in six of the sixteen years and for the models forecasting week 40 and week 47, the perfect weather forecasting model generated the best forecast for five and four of the sixteen years. The market model generated the best forecast for week 36 in four of the years and for both weeks 40 and 47 it generated the best forecast in seven years. For the same weeks, 36, 40, and 47 the current weather model generated the best forecast in six, four and five of the years respectively. The one week perfect model does not generate a forecast for week 47 because at that time it is the same as the perfect weather model. So for the weeks 36 and

40 it generated the best forecast in only one and two years respectively. However, the current and one week perfect weather models often have similar forecasts. For example the current weather model forecast for week 36 in 1990 was $3.37 per bushel, which was the most accurate forecast, and the one week perfect weather model forecasted $3.39 per bushel.

Table 4.6 shows the sum of the absolute errors for each week. The sum of the absolute errors for the first four weeks (36 to 39) is lower for the weather models compared to the market model. In the later weeks, specifically weeks 42, 43, 44, 45 and 47 the market model has the lowest absolute error sum. However, the error sum for all four models is generally quite close, such as in week 46, when the absolute error sum for the four models was 620, 624, 69 and 622.

4.2 Decision Analysis

4.2.1 Contract Prices

In this section the results of the decision analysis are presented. From week to week decision trees were used to determine the optimal amount of durum wheat to forward price. The prices that the durum quantities were forward contracted at are given in Table 4.7. As was discussed in chapter 3, the same pricing rules are used for each model. The forward contracting prices are the same for each model when the models all forecast either a decrease in price or no change in price. For example, in week 33 of 1980 all four models have the same forward contracting price of $7.07 per bushel. All models were forecasting no change in price for this week, so the forward contracting price is derived from the current price of $6.90 per bushel plus a 17 cents per bushel carrying charge. In week 23 of 1980, all models were forecasting large price increases. The contracting prices for this week are determined by the current price of $5.40 per bushel plus 50% of the price increase that the models were forecasting. Therefore the contracting prices for week 23 of 1980 are $6.08, $6.16, $6.10, and $6.11 per bushel for the market model, perfect weather model, current weather model and the one week perfect weather models respectively.

4.2.2 Contracting Volume

The quantity of durum to be forward contracted by the three weather models is determined weekly by a decision tree. Each week the decision model assumes that 2.2% of actual Canadian production is exported. The decision trees determine whether 1.76%, 1.1% or 0.44% of actual or forecasted production is forward contracted. In other words, either 80%, 50% or 20% of weekly exports are forward contracted. Table 4.8 shows the share of weekly exports the decision models choose as the optimal amount to forward contract. The only decision available in the market model was to forward contract 1.1% of expected production.

Each decision takes into consideration three states of nature, being a price increase, price decrease or no change in price. The revenue from each of these states of nature is weighted by its probability of occurring. If there is a high probability that the price will increase then the best decision is to forward price as little as possible so that in thirteen weeks when the expected price rises the increase can be realized for 80% of weekly exports. If there is a high probability of a price decrease then the optimal decision is to forward contract as much exports as possible so that if there is a price decrease there will be less grain to sell at the lower prices.

Table 4.8 shows that when a price increase is forecasted by the weather models the decision tree determines that forward contracting 20% of exports is the optimal decision. If a price increase actually occurs, this allows the decision maker to realize a higher price for the 80% of exports that were not forward contracted. When a decrease in price is forecasted by the weather models, the decision tree determines that forward contracting 80% of exports for that week is the optimal decision. By forward contracting such a large portion of exports the decision maker has protected himself somewhat against the risk of falling prices, which according to the forecast is a high risk. When the weather models forecast no change in price the decision tree chooses to forward contract either 80% or 20% of exports. The decision to forward contract 50% of exports is never chosen as the optimal decision. This is why from one week to the next within a year the quantity decisions sometimes changes from forward contracting 20% to forward contracting 80%. For example in 1980 the perfect weather model determines that forward contracting 20% of weekly exports is the optimal decision for each week except the last two weeks when it determines that the optimal decision is to forward contract 80% of exports. During these last two weeks the perfect weather model forecasts no change in the price. However for the previous week no change in price is also forecasted and the model determined the optimal decision to be forward contracting 20% of the week's exports. The reason for this sudden change in marketing strategy is illustrated in Figure 4.2.

Figure 4.2 shows the decision tree for the second last week of 1980 (week 46) when the decision to forward contract 80% of exports is chosen by the perfect weather model. The state of nature with the highest probability of occurring is no change in price at 64.1% with equal chance of an increase or decrease of 18.3 % and 17.6% respectively. The weighted average price which is likely to be realized when no price change is forecast and 80% of the durum is forward sold depends upon the contract prices for this volume and the remaining 20% sold later. For example, the weighted average price of 734 cents per bushel (Figure 4.2) is determined by the contract price of 707 cents per bushel (Table 4.7) and forward selling 80% at this price plus realizing 828 cents per bushel on the remaining 20% sold in week 46 if the market happened to increase when no change was forecast. A week 46 price of 828 cents per bushel is derived by increasing the current price of 690 cents per bushel in week 33 (Table 4.5) by 21.7% because the average price increase over the time period studied was 21.7%. The assumption being that if no price increase was forecast but in fact an increase occurred it would be the average of all increases. The expected value for the no change state of nature is 704 cents per bushel for the decision to forward contract 80%, which is weighted by its probability of occurring, .641. The expected value for the price increase state of nature is 734 cents per bushel which is weighted by .183 and the expected value for the price decrease state of the nature is 687 cents per bushel which is weighted by .176. The expected values for the three states of nature are weighted and then summed to 706 cents per bushel, which is the expected value for the decision to forward contract 80% of sales.

Figure 4.2 also shows the decision tree for week 45 of 1980 when no change in price is forecasted by the perfect weather model and the optimal decision is determined to be forward contracting 20% of exports. Week 45 is similar to week 46 in that the no change state of nature has the highest probability of occurring at almost 76%. However, there is a greater probability of a price increase than a price decrease in week 45. Therefore, although the expected value of the no change state of nature is greatest for the 80% decision and has a high weighting, the expected value of the price increase for the 20% decision is so much higher and has the next highest weighting that it increases the overall expected value of the 20% decision by a few cents over the 80% decision. When the expected values of the decision alternatives are as close as they are for weeks 45 and 46 of 1980, slight changes in the distribution of the probability weighting causes a reversal in the marketing strategy from one week to the next.

Therefore when no change in price is forecasted and a subsequent change in marketing strategy is recommended, the decision maker should examine the expected value of the marketing decision employed to date. If the expected value of that decision is less than 10 cents per bushel below the expected value of the recommended decision a change in marketing strategy is not needed. This means that in 1980 when no change in price is forecasted for the last three weeks and the recommended marketing strategy suddenly changes to forward contracting 80%, the decision maker would find that the expected value of the 20% forward contracting decision is only a few cents less than the recommended decision. Therefore the decision maker should stay with the 20% decision which is consistent with the rest of 1980. If the 20% decision was executed throughout

1980 some revenue would have been gained in week 45 when prices rose by 20 cents per bushel and some revenue would have been lost in week 46 when prices fell by 30 cents per bushel, but the marketing strategy would have been consistent throughout the year.

4.2.3 Comparison of the Models' Revenues

Each week the three weather models and the market model earn revenues from the sale of durum. These revenues are shown in Appendix B. The revenues generated by each model's weekly sales over the year are compared to the revenue from deferring all sales until after harvest. The results are presented in Table 4.9. The years in which deferring all sales generated more revenue than the forward contracting models were years in which fall prices were substantially higher than spring prices, such as in 1993 when the price of durum rose by almost $3.00 per bushel from spring to late fall. Generally though, the forward contracting models generated more revenue than the model that deferred all sales until fall. Over the 15 years studied the weather models generated between 20 and 28 million dollars more than the model that deferred all sales. The market model generated 9 million dollars more than the model that deferred all sales. Therefore forwarding contract a portion of exports every week adds value to the marketing of durum. Weather information used to forecast durum production allowed the portion of exports forward contracted each week to change as the expected price changed. This added value to the marketing of durum, shown by the weather model's revenue over the 15 years which was between 10 and 20 million dollars greater than the market model's revenue.

4.3 Summary

In this chapter parameters are estimated for the perfect weather model and the market model. The current weather model and the one week perfect weather models use the parameters estimated from the perfect weather model. From the parameter estimation price forecasts are generated for each model from 1980 to 1995. The second half of this chapter presents the results of the decision analysis models. Decision analysis is used to decide how much production to forward contract each week during the spring and summer months. The models are compared on how much revenue they generated from the decisions they recommended for each week from 1980 to 1994.

Figure 4.1

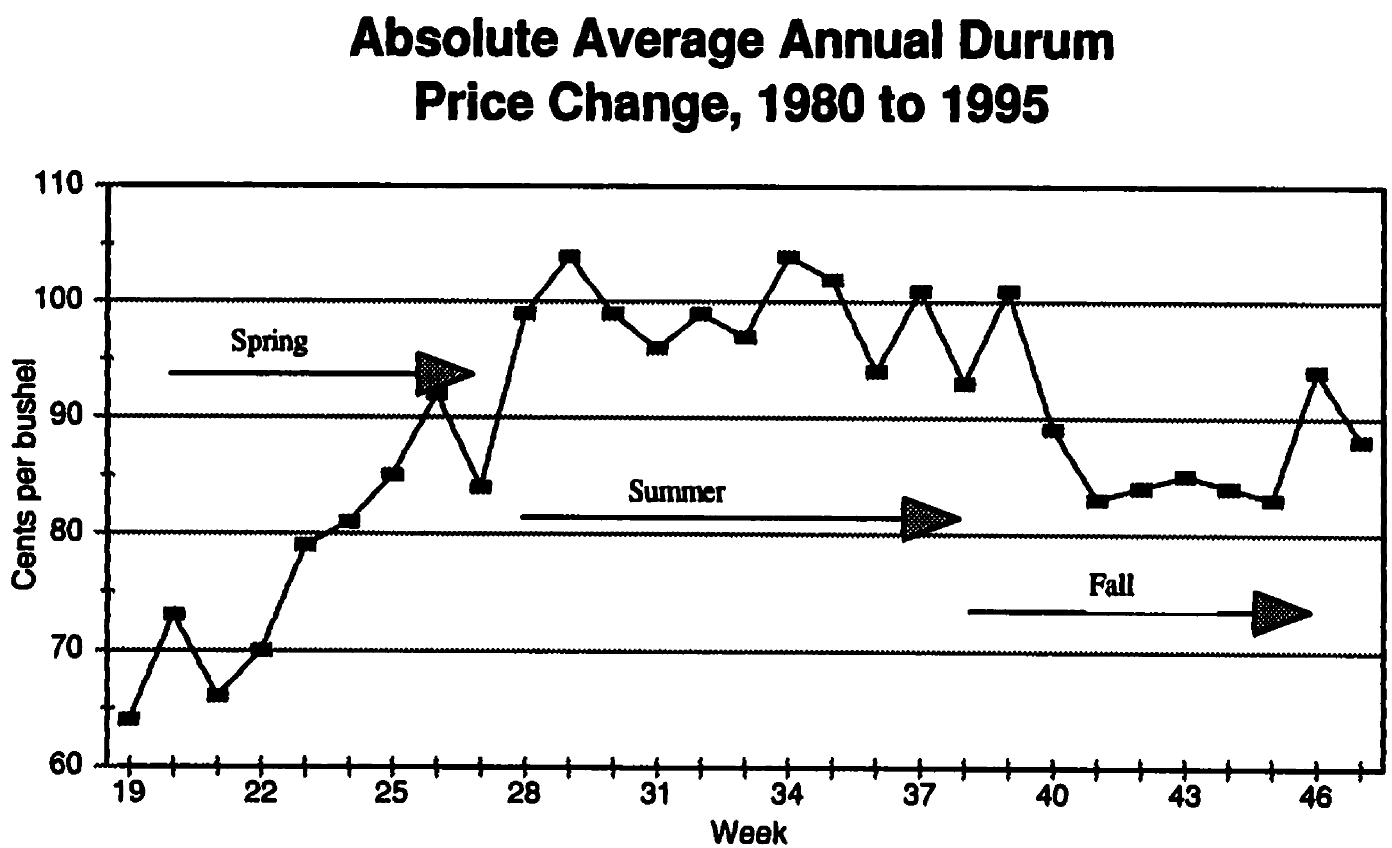
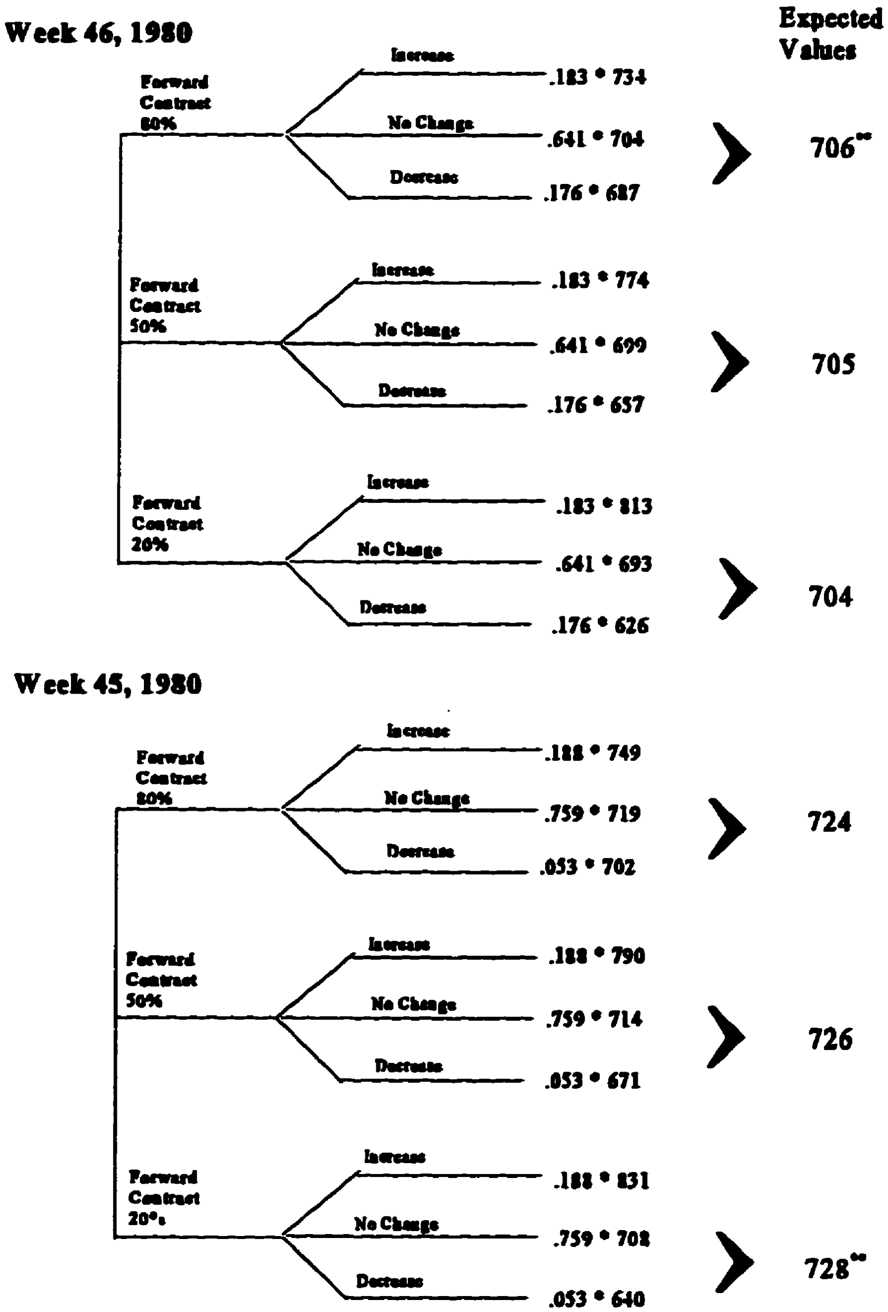

Absolute Average Annual Durum
Price Change, 1980 to 1995
Cents per bushel
110
100
90
80
70
60
Spring
Summer
Fall
19
22
25
28
31
34
37
40
43
46
Week

Figure 4.2 Decision Trees For Perfect Weather Model When No Change is Forecasted (Expected Values in cents/bushel)



**Optimal Decision

Table 4.1 Ordinary Least Squares Estimates of Market Model Parameters Used to Forecast the Annual Change in Durum Prices for Week 36 to Week 47.

Week 36 Equation Parameters

Independent Variables

Constant (¢/bu)	ΔP_{23} (¢/bu)	ΔP_{22} (¢/bu)	ΔP_{21} (¢/bu)	ΔP_{19} (¢/bu)	R^2	DW
-6.56	0.87	-3.24	4.72	-1.68	.79	2.04
(-.41)	(2.36)	(-2.73)	(4.14)	(-3.19)	student t-ratios	

where ΔP_i is the change in price for the i[th] week from the previous year

Week 37 Equation Parameters

Independent Variables

Constant (¢/bu)	ΔP_{24} (¢/bu)	ΔP_{22} (¢/bu)	ΔP_{21} (¢/bu)	ΔP_{19} (¢/bu)	R^2	DW
-6.81	1.10	-3.60	4.84	-1.57	.79	2.22
(-0.42)	(2.39)	(-2.22)	(3.44)	(-3.51)	student t-ratios	

where ΔP_i is the change in price for the i[th] week from the previous year

Week 38 Equation Parameters

Independent Variables

Constant (¢/bu)	ΔP_{25} (¢/bu)	ΔP_{24} (¢/bu)	R^2	DW
4.22	2.21	-1.48	.73	2.25
(0.27)	(3.97)	(-2.62)	student t-ratios	

where ΔP_i is the change in price for the i[th] week from the previous year

Week 39 Equation Parameters

Independent Variables

Constant (¢/bu)	ΔP_{26} (¢/bu)	ΔP_{24} (¢/bu)	ΔP_{23} (¢/bu)	R^2	DW
7.29	1.74	-1.84	0.92	.90	1.97
(0.83)	(6.15)	(-3.18)	(1.50)	student t-ratios	

where ΔP_i is the change in price for the i[th] week from the previous year

Table 4.1 (continued)

Week 40 Equation Parameters

Independent Variables

Constant (¢/bu)	ΔP_{26} (¢/bu)	ΔP_{24} (¢/bu)	R^2	DW
7.30	1.66	-0.95	.84	2.00
(0.73)	(5.69)	(-2.90)	student t-ratios	

where ΔP_i is the change in price for the i[th] week from the previous year

Week 41 Equation Parameters

Independent Variables

Constant (¢/bu)	ΔP_{27} (¢/bu)	ΔP_{25} (¢/bu)	R^2	DW
8.19	2.16	-1.47	.71	2.02
(0.61)	(3.65)	(-2.39)	student t-ratios	

where ΔP_i is the change in price for the i[th] week from the previous year

Week 42 Equation Parameters

Independent Variables

Constant (¢/bu)	ΔP_{29} (¢/bu)	ΔP_{28} (¢/bu)	ΔP_{27} (¢/bu)	R^2	DW
4.71	1.47	-2.61	2.04	.75	1.89
(0.44)	(2.57)	(-2.38)	(1.97)	student t-ratios	

where ΔP_i is the change in price for the i[th] week from the previous year

Week 43 Equation Parameters

Independent Variables

Constant (¢/bu)	ΔP_{30} (¢/bu)	ΔP_{28} (¢/bu)	R^2	DW
0.55	1.77	-0.98	.73	1.75
(0.05)	(3.20)	(-1.82)	student t-ratios	

where ΔP_i is the change in price for the i[th] week from the previous year

Table 4.1 (continued)

Week 44 Equation Parameters				
Independent Variables				
Constant (¢/bu)	ΔP_{31} (¢/bu)	ΔP_{29} (¢/bu)	R^2	DW
0.26	2.36	-1.39	.75	1.84
(0.02)	(3.08)	(-2.07)	student t-ratios	

where ΔP_i is the change in price for the i[th] week from the previous year

Week 45 Equation Parameters				
Independent Variables				
Constant (¢/bu)	ΔP_{32} (¢/bu)	ΔP_{29} (¢/bu)	R^2	DW
3.59	1.62	-0.80	.86	1.99
(0.30)	(5.03)	(-2.72)	student t-ratios	

where ΔP_i is the change in price for the i[th] week from the previous year

Week 46 Equation Parameters					
Independent Variables					
Constant (¢/bu)	ΔP_{33} (¢/bu)	ΔP_{32} (¢/bu)	ΔP_{31} (¢/bu)	R^2	DW
4.63	1.18	1.87	-2.36	.81	1.84
(0.23)	(1.60)	(2.10)	(-3.68)	student t-ratios	

where ΔP_i is the change in price for the i[th] week from the previous year

Week 47 Equation Parameters				
Independent Variables				
Constant (¢/bu)	ΔP_{32} (¢/bu)	ΔP_{31} (¢/bu)	R^2	DW
4.67	2.85	-2.24	.77	1.94
(0.23)	(4.50)	(-3.30)	student t-ratios	

where ΔP_i is the change in price for the i[th] week from the previous year

Table 4.2 Estimated Changes in the Prices of Durum Given a Consistent Change in Prices in the Spring and Summer.

Week	Each Variable Changing by (10¢/bushel)	Forecasted Price Change
		(¢/bushel)
36	ΔP_{23}, ΔP_{22}, ΔP_{21}, ΔP_{19}	6.7
37	ΔP_{24}, ΔP_{22}, ΔP_{21}, ΔP_{19}	7.7
38	ΔP_{25}, ΔP_{24}	7.3
39	ΔP_{26}, ΔP_{24}, ΔP_{23}	8.2
40	ΔP_{26}, ΔP_{24}	7.1
41	ΔP_{27}, ΔP_{25}	6.9
42	ΔP_{29}, ΔP_{28}, ΔP_{27}	9.0
43	ΔP_{30}, ΔP_{28}	7.9
44	ΔP_{31}, ΔP_{29}	9.7
45	ΔP_{32}, ΔP_{29}	8.2
46	ΔP_{33}, ΔP_{32}, ΔP_{31}	6.9
47	ΔP_{32}, ΔP_{31}	6.1

Table 4.3 Ordinary Least Squares Estimates of Perfect Weather Model Parameters Used to Forecast the Annual Change in Durum Prices for Week 36 to Week 47.

Week 36 Equation Parameters

Independent Variables

Constant (¢/bu)	ΔP_{22} (¢/bu)	ΔP_{21} (¢/bu)	ΔP_{19} (¢/bu)	ΔQ (1000T)	R^2	DW
2.55	-3.05	4.91	-1.62	-0.05	.91	1.86
(0.15)	(-6.02)	(8.63)	(-7.16)	(-6.04)	student t-ratios	

where ΔP_i is the change in price for the i^{th} week from the previous year

Week 37 Equation Parameters

Independent Variables

Constant (¢/bu)	ΔP_{22} (¢/bu)	ΔP_{21} (¢/bu)	ΔP_{19} (¢/bu)	ΔQ (1000T)	R^2	DW
-0.24	-1.98	3.92	-1.50	-0.04	.88	1.91
(-0.02)	(-2.71)	(4.73)	(-4.59)	(-4.27)	student t-ratios	

where ΔP_i is the change in price for the i^{th} week from the previous year

Week 38 Equation Parameters

Independent Variables

Constant (¢/bu)	ΔP_{25} (¢/bu)	ΔP_{24} (¢/bu)	ΔP_{22} (¢/bu)	ΔQ (1000T)	R^2	DW
3.20	2.24	-2.05	0.58	-0.01	.78	2.02
(0.26)	(3.48)	(-2.79)	(1.37)	(-0.69)	student t-ratios	

where ΔP_i is the change in price for the i^{th} week from the previous year

Week 39 Equation Parameters

Independent Variables

Constant (¢/bu)	ΔP_{26} (¢/bu)	ΔP_{25} (¢/bu)	ΔP_{24} (¢/bu)	ΔP_{23} (¢/bu)	ΔQ (1000T)	R^2	DW
8.80	2.39	-1.45	-1.47	1.24	-0.01	.92	1.94
(0.92)	(4.48)	(-1.51)	(-2.37)	(1.93)	(-1.12)	student t-ratios	

where ΔP_i is the change in price for the i^{th} week from the previous year

Table 4.3 (continued)

Week 40 Equation Parameters

Independent Variables

Constant (¢/bu)	ΔP_{26} (¢/bu)	ΔP_{24} (¢/bu)	ΔQ (1000T)	R^2	DW
7.92	1.61	-0.96	-0.01	.84	2.01
(0.72)	(5.36)	(-2.91)	(-0.54)	student t-ratios	

where ΔP_i is the change in price for the i^{th} week from the previous year

Week 41 Equation Parameters

Independent Variables

Constant (¢/bu)	ΔP_{27} (¢/bu)	ΔP_{25} (¢/bu)	ΔQ (1000T)	R^2	DW
10.6	2.19	-1.67	-0.02	.74	2.01
(0.73)	(3.72)	(-2.69)	(-1.18)	student t-ratios	

where ΔP_i is the change in price for the i^{th} week from the previous year

Week 42 Equation Parameters

Independent Variables

Constant (¢/bu)	ΔP_{29} (¢/bu)	ΔP_{28} (¢/bu)	ΔP_{27} (¢/bu)	ΔQ (1000T)	R^2	DW
7.63	1.67	-3.35	2.49	-0.02	.80	1.71
(0.79)	(2.91)	(-3.10)	(2.56)	(-1.57)	student t-ratios	

where ΔP_i is the change in price for the i^{th} week from the previous year

Week 43 Equation Parameters

Independent Variables

Constant (¢/bu)	ΔP_{30} (¢/bu)	ΔP_{28} (¢/bu)	ΔP_{27} (¢/bu)	ΔQ (1000T)	R^2	DW
7.13	1.91	-2.80	1.76	-0.02	.82	1.64
(0.78)	(3.64)	(-3.06)	(1.84)	(-1.72)	student t-ratios	

where ΔP_i is the change in price for the i^{th} week from the previous year

Table 4.3 (continued)

Week 44 Equation Parameters

Independent Variables

Constant (¢/bu)	ΔP_{31} (¢/bu)	ΔP_{29} (¢/bu)	ΔQ (1000T)	R^2	DW
0.37	2.30	-1.35	-0.002	.75	1.85
(0.03)	(2.77)	(-1.92)	(-0.18)	student t-ratios	

where ΔP_i is the change in price for the i[th] week from the previous year

Week 45 Equation Parameters

Independent Variables

Constant (¢/bu)	ΔP_{32} (¢/bu)	ΔP_{29} (¢/bu)	ΔQ (1000T)	R^2	DW
4.54	1.60	-0.85	-0.01	.87	2.01
(0.32)	(5.06)	(-2.97)	(-0.91)	student t-ratios	

where ΔP_i is the change in price for the i[th] week from the previous year

Week 46 Equation Parameters

Independent Variables

Constant (¢/bu)	ΔP_{33} (¢/bu)	ΔP_{32} (¢/bu)	ΔP_{31} (¢/bu)	ΔQ (1000T)	R^2	DW
8.33	1.25	1.91	-2.65	-0.02	.85	1.68
(0.32)	(2.03)	(2.49)	(-4.72)	(-1.73)	student t-ratios	

where ΔP_i is the change in price for the i[th] week from the previous year

Week 47 Equation Parameters

Independent Variables

Constant (¢/bu)	ΔP_{32} (¢/bu)	ΔP_{31} (¢/bu)	ΔQ (1000T)	R^2	DW
7.19	2.96	-2.50	-0.01	.79	1.91
(0.30)	(4.96)	(-3.88)	(-1.12)	student t-ratios	

where ΔP_i is the change in price for the i[th] week from the previous year

Table 4.4 Estimated Changes in the Price of Durum Given a Consistent Change in Price in the Spring and Summer.

Week	Each Variable Changing by (10¢/bushel)	Forecasted Price Change	Forecasted Price Change with a 100,000T Change in Supply
		(¢/bushel)	(¢/bushel)
36	$\Delta P_{22}, \Delta P_{21}, \Delta P_{19}$	2.4	4.7
37	$\Delta P_{22}, \Delta P_{21}, \Delta P_{19}$	4.4	4.5
38	$\Delta P_{25}, \Delta P_{24}, \Delta P_{22}$	7.7	1.1
39	$\Delta P_{26}, \Delta P_{25}, \Delta P_{24}, \Delta P_{23}$	7.1	1.1
40	$\Delta P_{26}, \Delta P_{24}$	6.5	0.6
41	$\Delta P_{27}, \Delta P_{25}$	5.2	1.7
42	$\Delta P_{29}, \Delta P_{28}, \Delta P_{27}$	8.1	1.9
43	$\Delta P_{30}, \Delta P_{28}, \Delta P_{27}$	8.7	2.0
44	$\Delta P_{31}, \Delta P_{29}$	9.5	0.2
45	$\Delta P_{32}, \Delta P_{29}$	7.5	0.8
46	$\Delta P_{33}, \Delta P_{32}, \Delta P_{31}$	5.1	1.9
47	$\Delta P_{32}, \Delta P_{31}$	4.6	1.4

Table 4.5 Actual Current Price, Actual Price in Thirteen Weeks and Thirteen Week Forecasts for Each Model (cents/bu)

Year	Actual Week 23	Actual Week 36	Market Forecast	Perfect Weather Forecast	Current Weather Forecast	One Week Perfect Forecast
1980	540	700	675	692	679	683
1981	470	440	486	473	479	477
1982	415	385	490	450	483	483
1983	475	480	476	525	529	532
1984	450	440	376	454	436	438
1985	410	385	406	432	409	410
1986	390	290	361	284	303	307
1987	386	425	402	392	390	390
1988	575	470	450	484	378	395
1989	440	415	403	458	421	421
1990	410	315	344	291	337	339
1991	320	305	232	254	284	276
1992	395	370	357	386	433	436
1993	375	500	407	464	516	516
1994	525	585	630	537	538	533
1995	700	690	701	654	671	671

Year	Actual Week 24	Actual Week 37	Market Forecast	Perfect Weather Forecast	Current Weather Forecast	One Week Perfect Forecast
1980	535	700	679	702	691	694
1981	465	450	491	464	465	465
1982	415	378	498	439	468	468
1983	468	505	467	513	516	519
1984	445	440	397	486	469	470
1985	408	372	406	418	397	399
1986	385	305	334	284	302	306
1987	335	410	377	368	365	365
1988	550	500	486	510	411	427
1989	435	405	427	473	438	438
1990	415	315	349	275	318	319
1991	315	315	212	238	265	258
1992	395	385	380	404	447	450
1993	375	500	421	458	507	507
1994	485	560	606	553	553	549
1995	700	715	726	676	691	692

Table 4.5 (continued)

Year	Actual Week 25	Actual Week 38	Market Forecast	Perfect Weather Forecast	Current Weather Forecast	One Week Perfect Forecast
1980	575	695	620	646	645	646
1981	440	435	505	482	480	479
1982	409	385	445	409	416	417
1983	472	505	450	471	474	475
1984	450	430	495	505	502	503
1985	410	375	401	398	394	395
1986	340	320	259	251	258	259
1987	360	395	442	447	448	451
1988	550	470	500	462	445	449
1989	435	385	391	442	433	433
1990	400	320	342	302	313	314
1991	310	330	274	269	273	272
1992	390	380	392	403	415	416
1993	375	500	381	385	396	395
1994	485	610	584	601	599	599
1995	700	715	771	766	770	770

Year	Actual Week 26	Actual Week 39	Market Forecast	Perfect Weather Forecast	Current Weather Forecast	One Week Perfect Forecast
1980	660	750	728	764	764	765
1981	450	440	441	450	447	446
1982	405	390	419	379	387	388
1983	472	495	467	479	482	481
1984	440	425	469	477	475	476
1985	390	380	381	376	372	374
1986	330	310	301	331	340	340
1987	365	395	440	439	443	445
1988	525	470	469	470	457	458
1989	430	400	427	400	391	392
1990	385	320	346	329	342	344
1991	305	335	289	298	301	301
1992	390	380	416	419	433	433
1993	380	500	392	401	411	410
1994	480	625	576	602	600	600
1995	700	750	812	754	759	759

Table 4.5 (continued)

Year	Actual Week 27	Actual Week 40	Market Forecast	Perfect Weather Forecast	Current Weather Forecast	One Week Perfect Forecast
1980	660	725	724	721	722	722
1981	440	445	450	453	451	450
1982	400	387	425	422	427	426
1983	460	467	455	459	461	460
1984	435	428	443	454	453	454
1985	390	375	387	391	389	390
1986	330	320	304	295	300	300
1987	360	390	433	431	434	433
1988	515	470	459	470	464	464
1989	440	405	429	425	421	422
1990	380	330	357	352	360	357
1991	305	345	299	302	304	304
1992	385	365	418	419	427	426
1993	390	500	375	381	386	384
1994	480	625	569	557	556	556
1995	700	730	794	783	785	785

Year	Actual Week 28	Actual Week 41	Market Forecast	Perfect Weather Forecast	Current Weather Forecast	One Week Perfect Forecast
1980	670	715	687	688	690	688
1981	442	440	446	443	436	435
1982	390	395	407	397	407	405
1983	472	485	440	453	455	454
1984	440	435	471	501	501	504
1985	395	368	405	413	412	415
1986	285	315	349	327	340	335
1987	335	400	359	352	359	356
1988	500	470	464	493	477	479
1989	435	410	485	479	469	470
1990	370	335	340	325	339	335
1991	290	355	313	323	328	327
1992	385	365	419	425	444	440
1993	390	570	406	426	433	426
1994	480	625	611	578	573	573
1995	745	700	793	765	772	771

Table 4.5 (continued)

Year	Actual Week 29	Actual Week 42	Market Forecast	Perfect Weather Forecast	Current Weather Forecast	One Week Perfect Forecast
1980	745	725	760	762	763	762
1981	440	440	424	407	398	397
1982	405	395	447	443	452	449
1983	475	468	412	418	419	418
1984	470	440	498	537	541	543
1985	385	375	344	342	345	348
1986	285	325	396	393	402	398
1987	330	400	327	310	313	310
1988	475	480	506	551	536	538
1989	440	410	449	427	417	418
1990	360	330	343	327	337	333
1991	290	340	287	292	295	295
1992	360	360	364	367	383	379
1993	390	570	406	429	429	422
1994	525	625	723	710	705	705
1995	745	700	714	671	678	678

Year	Actual Week 30	Actual Week 43	Market Forecast	Perfect Weather Forecast	Current Weather Forecast	One Week Perfect Forecast
1980	720	725	824	788	788	787
1981	440	450	454	416	405	404
1982	400	395	431	435	441	438
1983	470	475	439	437	437	436
1984	420	440	419	458	465	467
1985	380	370	414	415	421	424
1986	280	330	302	345	350	347
1987	340	390	388	359	359	356
1988	475	480	467	537	523	524
1989	435	405	474	426	417	418
1990	360	325	337	319	325	321
1991	290	355	280	280	283	282
1992	360	360	386	392	405	402
1993	400	600	426	455	447	444
1994	525	625	733	735	731	731
1995	700	700	675	622	629	629

Table 4.5 (continued)

Year	Actual Week 31	Actual Week 44	Market Forecast	Perfect Weather Forecast	Current Weather Forecast	One Week Perfect Forecast
1980	705	705	781	779	779	779
1981	450	455	528	529	528	528
1982	385	397	350	351	351	351
1983	470	480	500	501	501	501
1984	440	435	416	421	423	423
1985	370	365	388	390	391	391
1986	280	330	292	289	289	289
1987	340	390	409	406	406	406
1988	460	480	472	478	476	476
1989	435	390	470	466	465	465
1990	335	320	266	266	266	266
1991	295	355	323	322	322	322
1992	355	370	399	401	402	402
1993	410	600	458	458	457	457
1994	525	625	684	679	679	679
1995	675	700	673	673	674	674

Year	Actual Week 32	Actual Week 45	Market Forecast	Perfect Weather Forecast	Current Weather Forecast	One Week Perfect Forecast
1980	705	705	733	727	727	726
1981	415	450	484	494	489	490
1982	380	400	425	419	420	420
1983	495	478	534	539	539	540
1984	475	440	453	466	470	470
1985	370	380	342	349	352	352
1986	275	340	310	300	300	300
1987	355	390	437	431	429	429
1988	465	480	455	477	471	471
1989	420	390	439	428	425	425
1990	325	325	304	300	301	301
1991	297	355	339	340	342	342
1992	345	375	380	386	389	389
1993	435	600	500	505	500	500
1994	500	625	600	585	584	584
1995	650	700	695	685	688	688

Table 4.5 (continued)

Year	Actual Week 33	Actual Week 46	Market Forecast	Perfect Weather Forecast	Current Weather Forecast	One Week Perfect Forecast
1980	690	710	708	693	691	690
1981	430	440	464	484	475	476
1982	380	400	473	471	471	471
1983	510	462	574	589	591	592
1984	445	440	423	456	466	466
1985	370	385	324	338	345	344
1986	280	325	317	296	297	297
1987	365	400	439	428	422	422
1988	465	480	446	494	482	482
1989	425	395	412	385	380	380
1990	325	320	339	336	339	340
1991	305	340	343	346	350	351
1992	330	370	323	333	340	339
1993	435	680	538	552	542	542
1994	500	600	612	572	568	568
1995	650	700	710	694	702	702

Year	Actual Week 34	Actual Week 47	Market Forecast	Perfect Weather Forecast	Current Weather Forecast
1980	730	700	716	704	702
1981	430	420	449	463	457
1982	375	405	470	471	471
1983	515	445	547	558	560
1984	447	438	460	487	495
1985	375	385	300	308	313
1986	265	340	320	305	305
1987	375	400	438	430	425
1988	465	480	450	484	475
1989	425	395	412	391	388
1990	335	310	353	352	354
1991	310	345	324	327	330
1992	330	370	352	360	364
1993	435	670	508	518	511
1994	500	600	603	569	567
1995	640	700	697	683	689

Table 4.6 Sum of the Absolute Errors for the Price Forecasting Models

	Market Model	Perfect Weather Model	Current Weather Model	One Week Perfect Weather Model
Week 36	657	518	569	569
Week 37	674	543	500	499
Week 38	785	713	706	705
Week 39	534	384	425	429
Week 40	546	539	551	549
Week 41	691	683	683	692
Week 42	801	857	859	861
Week 43	772	810	821	830
Week 44	746	729	728	728
Week 45	515	526	527	527
Week 46	620	624	619	622
Week 47	674	694	689	

Table 4.7 Forward Contracting Price Determination for Sales Decisions (US cents/bu)

1980					
Week	Current Price	Market Model	Perfect Weather	Current Weather	One Wk Perfect
23 for 36	540	608	616	610	611
24 for 37	535	607	619	613	614
25 for 38	575	598	610	610	610
26 for 39	660	697	697	697	697
27 for 40	660	692	691	691	691
28 for 41	670	687	687	687	687
29 for 42	745	762	762	762	762
30 for 43	720	772	754	754	754
31 for 44	705	743	742	742	742
32 for 45	705	722	722	722	722
33 for 46	690	707	707	707	707
34 for 47	730	747	747	747	730

1981					
Week	Current Price	Market Model	Perfect Weather	Current Weather	One Wk Perfect
23 for 36	470	490	490	490	490
24 for 37	465	485	485	485	485
25 for 38	440	472	461	460	460
26 for 39	450	470	470	470	470
27 for 40	440	460	460	460	460
28 for 41	442	462	462	462	462
29 for 42	440	460	440	440	440
30 for 43	440	460	460	440	440
31 for 44	450	489	490	489	489
32 for 45	415	449	454	452	452
33 for 46	430	450	457	452	453
34 for 47	430	450	450	450	430

Table 4.7 (Continued)

1982					
Week	Current Price	Market Model	Perfect Weather	Current Weather	One Wk Perfect
23 for 36	415	453	435	449	449
24 for 37	415	456	435	442	442
25 for 38	409	429	429	429	429
26 for 39	405	425	425	425	425
27 for 40	400	420	420	420	420
28 for 41	390	410	410	410	410
29 for 42	405	426	425	429	427
30 for 43	400	420	420	420	420
31 for 44	385	385	385	385	385
32 for 45	380	403	400	400	400
33 for 46	380	427	425	426	425
34 for 47	375	423	423	423	375

1983					
Week	Current Price	Market Model	Perfect Weather	Current Weather	One Wk Perfect
23 for 36	475	491	500	502	504
24 for 37	468	484	490	492	493
25 for 38	472	488	488	488	488
26 for 39	472	488	488	488	488
27 for 40	460	476	476	476	476
28 for 41	472	488	488	488	488
29 for 42	475	475	475	475	475
30 for 43	470	486	470	470	470
31 for 44	470	486	486	486	486
32 for 45	495	514	517	517	517
33 for 46	510	542	550	551	551
34 for 47	515	531	537	538	515

Table 4.7 (Continued)

1984					
Week	Current Price	Market Model	Perfect Weather	Current Weather	One Wk Perfect
23 for 36	450	450	464	464	464
24 for 37	445	445	465	459	459
25 for 38	450	472	478	476	476
26 for 39	440	454	459	457	458
27 for 40	435	449	449	449	449
28 for 41	440	456	470	471	472
29 for 42	470	484	500	500	500
30 for 43	420	434	439	443	444
31 for 44	440	454	454	454	454
32 for 45	475	489	489	489	489
33 for 46	445	459	459	459	459
34 for 47	447	461	467	471	447

1985					
Week	Current Price	Market Model	Perfect Weather	Current Weather	One Wk Perfect
23 for 36	410	425	425	425	425
24 for 37	408	423	423	423	423
25 for 38	410	425	425	425	425
26 for 39	390	405	405	405	405
27 for 40	390	405	405	405	405
28 for 41	395	410	410	410	410
29 for 42	385	385	385	385	385
30 for 43	380	397	398	401	402
31 for 44	370	385	385	385	385
32 for 45	370	370	385	385	385
33 for 46	370	370	370	385	385
34 for 47	375	375	375	375	375

Table 4.7 (Continued)

1986					
Week	Current Price	Market Model	Perfect Weather	Current Weather	One Wk Perfect
23 for 36	390	390	390	390	390
24 for 37	385	385	385	385	385
25 for 38	340	340	340	340	340
26 for 39	330	330	343	343	343
27 for 40	330	330	330	330	330
28 for 41	285	317	306	313	310
29 for 42	285	341	339	343	342
30 for 43	280	293	313	315	313
31 for 44	280	293	293	293	293
32 for 45	275	293	288	288	288
33 for 46	280	299	293	293	293
34 for 47	265	293	285	285	265

1987					
Week	Current Price	Market Model	Perfect Weather	Current Weather	One Wk Perfect
23 for 36	386	395	395	395	395
24 for 37	335	356	351	350	350
25 for 38	360	401	403	404	405
26 for 39	365	403	396	396	396
27 for 40	360	397	393	393	393
28 for 41	335	347	344	347	344
29 for 42	330	339	339	339	339
30 for 43	340	364	349	349	349
31 for 44	340	375	373	373	373
32 for 45	355	396	386	386	386
33 for 46	365	402	388	388	388
34 for 47	375	407	401	400	375

Table 4.7 (Continued)

1988					
Week	Current Price	Market Model	Perfect Weather	Current Weather	One Wk Perfect
23 for 36	575	575	575	575	575
24 for 37	550	550	550	550	550
25 for 38	550	550	550	550	550
26 for 39	525	525	525	525	525
27 for 40	515	515	515	515	515
28 for 41	500	500	512	512	512
29 for 42	475	487	513	505	506
30 for 43	475	487	506	499	499
31 for 44	460	472	472	472	472
32 for 45	465	477	477	477	477
33 for 46	465	477	477	477	477
34 for 47	465	477	477	477	465

1989					
Week	Current Price	Market Model	Perfect Weather	Current Weather	One Wk Perfect
23 for 36	440	440	455	455	455
24 for 37	435	450	454	450	450
25 for 38	435	435	450	450	450
26 for 39	430	445	445	430	430
27 for 40	440	455	455	455	455
28 for 41	435	460	457	452	452
29 for 42	440	455	455	455	455
30 for 43	435	454	450	450	450
31 for 44	435	452	451	450	450
32 for 45	420	435	435	435	435
33 for 46	425	440	425	425	425
34 for 47	425	440	425	425	425

Table 4.7 (Continued)

1990					
Week	Current Price	Market Model	Perfect Weather	Current Weather	One Wk Perfect
23 for 36	410	410	410	410	410
24 for 37	415	415	415	415	415
25 for 38	400	400	400	400	400
26 for 39	385	385	385	385	385
27 for 40	380	399	380	399	399
28 for 41	370	370	370	370	370
29 for 42	360	379	360	379	360
30 for 43	360	379	360	360	360
31 for 44	335	335	335	335	335
32 for 45	325	344	325	325	325
33 for 46	325	344	344	344	344
34 for 47	335	354	354	354	335

1991					
Week	Current Price	Market Model	Perfect Weather	Current Weather	One Wk Perfect
23 for 36	320	320	320	320	320
24 for 37	315	315	315	315	315
25 for 38	310	310	310	310	310
26 for 39	305	321	321	321	321
27 for 40	305	321	321	321	321
28 for 41	290	306	307	309	308
29 for 42	290	306	306	306	306
30 for 43	290	306	306	306	306
31 for 44	295	311	311	311	311
32 for 45	297	318	319	319	320
33 for 46	305	324	325	327	328
34 for 47	310	326	326	326	310

Table 4.7 (Continued)

1992					
Week	Current Price	Market Model	Perfect Weather	Current Weather	One Wk Perfect
23 for 36	395	395	406	414	415
24 for 37	395	406	406	421	422
25 for 38	390	401	401	401	401
26 for 39	390	401	404	411	412
27 for 40	385	401	402	406	405
28 for 41	385	402	405	414	413
29 for 42	360	371	371	371	371
30 for 43	360	373	376	383	381
31 for 44	355	377	378	379	378
32 for 45	345	363	365	367	367
33 for 46	330	341	341	341	341
34 for 47	330	341	345	347	330

1993					
Week	Current Price	Market Model	Perfect Weather	Current Weather	One Wk Perfect
23 for 36	375	391	419	439	439
24 for 37	375	398	417	439	439
25 for 38	375	386	386	386	386
26 for 39	380	391	391	396	395
27 for 40	390	401	401	401	401
28 for 41	390	464	408	412	408
29 for 42	390	469	410	410	406
30 for 43	400	479	427	424	422
31 for 44	410	473	434	433	433
32 for 45	435	495	470	468	468
33 for 46	435	502	493	488	489
34 for 47	435	507	477	473	435

Table 4.7 (Continued)

1994					
Week	Current Price	Market Model	Perfect Weather	Current Weather	One Wk Perfect
23 for 36	525	578	534	534	534
24 for 37	485	546	519	519	517
25 for 38	485	535	543	542	542
26 for 39	480	528	541	540	540
27 for 40	480	524	519	518	518
28 for 41	480	546	529	527	527
29 for 42	525	624	601	601	601
30 for 43	525	629	591	591	591
31 for 44	525	604	575	575	575
32 for 45	500	550	543	542	542
33 for 46	500	556	536	534	534
34 for 47	500	551	535	533	500

Table 4.8 Share of Weekly Exports Forward Contracted and the Direction of the Price Forecast, (Price Increase = + Price Decrease = - No Change = nc)

1980

	Perfect Weather		Current Weather		One Wk Perfect Weather	
Week	Quantity	Price	Quantity	Price	Quantity	Price
36	20%	+	20%	+	20%	+
37	20%	+	20%	+	20%	+
38	20%	+	20%	+	20%	+
39	20%	+	20%	+	20%	+
40	20%	+	20%	+	20%	+
41	20%	nc	20%	nc	20%	nc
42	20%	nc	80%	nc	20%	nc
43	20%	+	20%	+	20%	+
44	20%	+	20%	+	20%	+
45	20%	nc	20%	nc	20%	nc
46	80%	nc	80%	nc	80%	nc
47	80%	nc	80%	nc		

1981

	Perfect Weather		Current Weather		One Wk Perfect Weather	
Week	Quantity	Price	Quantity	Price	Quantity	Price
36	80%	nc	80%	nc	80%	nc
37	80%	nc	80%	nc	80%	nc
38	20%	+	20%	+	20%	+
39	80%	nc	80%	nc	80%	nc
40	80%	nc	80%	nc	80%	nc
41	80%	nc	80%	nc	80%	nc
42	80%	-	80%	-	80%	-
43	80%	nc	80%	-	80%	-
44	20%	+	20%	+	20%	+
45	20%	+	20%	+	20%	+
46	20%	+	20%	+	20%	+
47	20%	+	80%	nc		

Table 4.8 (Continued)

1982

	Perfect Weather		Current Weather		One Wk Perfect Weather	
Week	Quantity	Price	Quantity	Price	Quantity	Price
36	20%	+	20%	+	20%	+
37	20%	nc	20%	+	20%	+
38	80%	nc	80%	nc	80%	nc
39	80%	nc	80%	nc	80%	+
40	20%	nc	20%	nc	20%	nc
41	80%	nc	80%	nc	80%	nc
42	20%	+	20%	+	20%	+
43	20%	+	20%	+	20%	+
44	80%	-	80%	-	80%	-
45	20%	+	20%	+	20%	+
46	20%	+	20%	+	20%	+
47	20%	+	20%	+		

1983

	Perfect Weather		Current Weather		One Wk Perfect Weather	
Week	Quantity	Price	Quantity	Price	Quantity	Price
36	20%	+	20%	+	20%	+
37	20%	+	20%	+	20%	+
38	80%	nc	80%	nc	80%	nc
39	80%	nc	80%	nc	80%	nc
40	80%	nc	80%	nc	80%	nc
41	80%	nc	80%	nc	80%	nc
42	80%	-	80%	-	80%	-
43	80%	-	80%	-	80%	-
44	20%	nc	20%	nc	20%	nc
45	20%	+	20%	+	20%	+
46	20%	+	20%	+	20%	+
47	20%	+	20%	+		

Table 4.8 (Continued)

	1984					
	Perfect Weather		Current Weather		One Wk Perfect Weather	
Week	Quantity	Price	Quantity	Price	Quantity	Price
36	80%	nc	80%	nc	80%	nc
37	20%	+	20%	nc	20%	nc
38	20%	+	20%	+	20%	+
39	20%	+	20%	+	20%	nc
40	20%	nc	20%	nc	20%	nc
41	20%	+	20%	+	20%	+
42	20%	+	20%	+	20%	+
43	20%	+	20%	+	20%	+
44	80%	nc	80%	nc	80%	nc
45	80%	nc	80%	nc	80%	nc
46	20%	nc	20%	nc	20%	nc
47	20%	+	20%	+		

	1985					
	Perfect Weather		Current Weather		One Wk Perfect Weather	
Week	Quantity	Price	Quantity	Price	Quantity	Price
36	20%	nc	80%	nc	80%	nc
37	80%	nc	80%	nc	80%	nc
38	80%	nc	80%	nc	80%	nc
39	80%	nc	80%	nc	80%	-
40	80%	nc	80%	nc	80%	nc
41	20%	nc	80%	nc	20%	nc
42	80%	-	80%	-	80%	-
43	20%	+	20%	+	20%	+
44	20%	nc	80%	nc	20%	nc
45	80%	nc	80%	nc	80%	nc
46	80%	-	80%	nc	80%	nc
47	80%	-	80%	-		

Table 4.8 (Continued)

1986

	Perfect Weather		Current Weather		One Wk Perfect Weather	
Week	Quantity	Price	Quantity	Price	Quantity	Price
36	80%	-	80%	-	80%	-
37	80%	-	80%	-	80%	-
38	80%	-	80%	-	80%	-
39	80%	nc	80%	nc	80%	nc
40	80%	-	80%	-	80%	-
41	20%	+	20%	+	20%	+
42	20%	+	20%	+	20%	+
43	20%	+	20%	+	20%	+
44	80%	nc	80%	nc	80%	nc
45	20%	+	20%	+	20%	+
46	20%	nc	80%	nc	80%	nc
47	20%	+	20%	+		

1987

	Perfect Weather		Current Weather		One Wk Perfect Weather	
Week	Quantity	Price	Quantity	Price	Quantity	Price
36	20%	nc	80%	nc	80%	nc
37	20%	+	20%	+	20%	+
38	20%	+	20%	+	20%	+
39	20%	+	20%	+	20%	+
40	20%	+	20%	+	20%	+
41	20%	nc	20%	+	20%	nc
42	80%	nc	80%	nc	80%	nc
43	20%	nc	20%	nc	20%	nc
44	20%	+	20%	+	20%	+
45	20%	+	20%	+	20%	+
46	20%	+	20%	+	20%	+
47	20%	+	20%	+		

Table 4. 8 (Continued)

	1988					
	Perfect Weather		Current Weather		One Wk Perfect Weather	
Week	Quantity	Price	Quantity	Price	Quantity	Price
36	80%	-	80%	-	80%	-
37	80%	-	80%	-	80%	-
38	80%	-	80%	-	80%	-
39	80%	-	80%	-	80%	-
40	80%	-	80%	-	80%	-
41	80%	nc	80%	nc	80%	nc
42	20%	+	20%	+	20%	+
43	20%	+	20%	+	20%	+
44	20%	nc	20%	nc	20%	nc
45	20%	nc	80%	nc	80%	nc
46	20%	nc	20%	nc	20%	nc
47	20%	nc	80%	nc		

	1989					
	Perfect Weather		Current Weather		One Wk Perfect Weather	
Week	Quantity	Price	Quantity	Price	Quantity	Price
36	20%	nc	80%	nc	80%	nc
37	20%	+	80%	nc	80%	nc
38	80%	nc	80%	nc	80%	nc
39	80%	nc	80%	-	80%	-
40	80%	nc	80%	nc	80%	nc
41	20%	+	20%	+	20%	+
42	80%	nc	80%	nc	80%	nc
43	80%	nc	80%	nc	80%	nc
44	20%	+	20%	nc	20%	nc
45	80%	nc	80%	nc	80%	nc
46	80%	-	80%	-	80%	-
47	80%	-	80%	-		

Table 4. 8 (Continued)

1990

	Perfect Weather		Current Weather		One Wk Perfect Weather	
Week	Quantity	Price	Quantity	Price	Quantity	Price
36	80%	-	80%	-	80%	-
37	80%	-	80%	-	80%	-
38	80%	-	80%	-	80%	-
39	80%	-	80%	-	80%	nc
40	80%	-	80%	nc	80%	nc
41	80%	-	80%	-	80%	-
42	80%	-	80%	nc	80%	-
43	80%	-	80%	-	80%	-
44	80%	-	80%	-	80%	-
45	80%	-	80%	-	80%	-
46	80%	nc	80%	nc	80%	nc
47	80%	nc	80%	nc		

1991

	Perfect Weather		Current Weather		One Wk Perfect Weather	
Week	Quantity	Price	Quantity	Price	Quantity	Price
36	80%	-	80%	-	80%	-
37	80%	-	80%	-	80%	-
38	80%	-	80%	-	80%	-
39	80%	nc	80%	nc	80%	nc
40	80%	nc	80%	nc	80%	nc
41	20%	+	20%	+	20%	+
42	80%	nc	80%	nc	80%	nc
43	80%	nc	80%	nc	80%	nc
44	20%	+	20%	+	20%	+
45	20%	+	20%	+	20%	+
46	20%	+	20%	+	20%	+
47	20%	nc	80%	-		

Table 4.8 (Continued)

1992

	Perfect Weather		Current Weather		One Wk Perfect Weather	
Week	Quantity	Price	Quantity	Price	Quantity	Price
36	80%	nc	20%	+	20%	+
37	20%	nc	20%	+	20%	+
38	20%	nc	20%	nc	20%	nc
39	20%	+	20%	+	20%	+
40	20%	+	20%	+	20%	+
41	20%	+	20%	+	20%	+
42	20%	nc	20%	nc	20%	nc
43	20%	+	20%	+	20%	+
44	20%	+	20%	+	20%	+
45	20%	+	20%	+	20%	+
46	80%	nc	80%	nc	80%	nc
47	20%	+	20%	+		

1993

	Perfect Weather		Current Weather		One Wk Perfect Weather	
Week	Quantity	Price	Quantity	Price	Quantity	Price
36	20%	+	20%	+	20%	+
37	20%	+	20%	+	20%	+
38	20%	nc	20%	nc	20%	nc
39	20%	nc	20%	+	20%	+
40	80%	nc	80%	nc	80%	nc
41	20%	+	20%	+	20%	+
42	20%	+	20%	+	20%	+
43	20%	+	20%	+	20%	+
44	20%	+	20%	+	20%	+
45	20%	+	20%	+	20%	+
46	20%	+	20%	+	20%	+
47	20%	+	20%	+		

Table 4.8 (Continued)

	1994					
	Perfect Weather		Current Weather		One Wk Perfect Weather	
Week	Quantity	Price	Quantity	Price	Quantity	Price
36	20%	nc	20%	nc	20%	nc
37	20%	+	20%	+	20%	+
38	20%	+	20%	+	20%	+
39	20%	+	20%	+	20%	+
40	20%	+	20%	+	20%	+
41	20%	+	20%	+	20%	+
42	20%	+	20%	+	20%	+
43	20%	+	20%	+	20%	+
44	20%	+	20%	+	20%	+
45	20%	+	20%	+	20%	+
46	20%	+	20%	+	20%	+
47	20%	+	20%	+		

Table 4.9 Total Annual Deferred Revenue Compared to Forward Sales Revenue in Millions of US$.

		Difference Between Deferred and Forward Sales			
Year	Total Revenue all Deferred Sales	Market Model	Perfect Weather Model	Current Weather Model	One Week Perfect Weather Model
1980	141.0	-1.8	-0.7	1.0	-0.6
1981	127.4	3.3	3.6	3.6	3.5
1982	118.8	3.5	3.0	2.5	2.5
1983	121.7	1.9	0.7	0.8	0.8
1984	88.4	3.2	1.5	2.2	2.2
1985	70.5	3.0	2.3	4.6	3.8
1986	120.7	0.6	4.9	3.1	3.0
1987	155.2	-3.0	-1.7	-3.3	-3.4
1988	88.2	5.5	4.8	6.8	6.4
1989	160.8	9.8	6.9	12.9	12.2
1990	131.0	9.2	12.5	14.8	13.5
1991	150.9	-4.0	-3.1	-5.3	-4.9
1992	112.9	1.2	1.3	0.4	0.4
1993	184.5	-14.4	-10.6	-9.7	-10.2
1994	274.5	-9.0	-5.7	-6.2	-6.2
Total		9.0	19.7	28.2	23.0

Chapter V

Summary and Conclusions

5.1 Summary

Access to information is essential in the establishment of an efficient pricing system. Agricultural markets are dependent on weather to produce high quality products, however, weather and the uncertainty that surrounds it creates uncertainty about the quantity and quality of these products. Therefore there may be value in weather information that can reduce this uncertainty. This study examines the case of durum wheat and the Canadian Wheat Board to find the value of weather information.

Durum wheat is grown only in only a few regions. Canada, the United States and the EU produce most of the world's high protein durum and account for approximately 95 percent of world durum exports. Changes in durum supply are more important in determining the durum price than shifts in demand. Durum wheat does not have a futures market, and the closest substitute, hard red spring wheat, is not a reliable indicator of future durum prices. This study examines whether weather information during the growing season has predictive power for forecasting future durum prices and whether weather information can be used to improve the marketing strategy of a single desk seller such as the Canadian Wheat Board through forward contracting.

Three different types of weather information are used to predict future durum prices; perfect knowledge of weather for the entire growing season, a perfect weather forecast for one week and average historical weather for the remaining portion of the growing season and; knowledge of weather only up to the current period and average historical weather for the remaining portion of the growing season. A drought index is used to incorporate this weather information from the durum producing area in North America and estimate durum production for each crop year. Durum production is then used in a supply variable to help forecast future durum prices. The durum price forecasts that used each type of weather information are compared to each other and to durum price forecasts which used no weather information to forecast the price.

The price forecasts from the three different types of weather information and the price forecasts that used no weather information are then used in decision analysis models. The decision analysis models are used to find the optimal amount of durum to forward price during the growing season and the optimal amount to defer pricing until the time of export.

The decision analysis models that include weather information allow three different quantities of durum to be forward sold and the decision analysis model that does not include weather information only allows one quantity of durum to be forward sold. Each week of the growing season a decision is made by each of the four decision models on how much durum to forward price and how much to defer pricing for thirteen weeks, which is the average time it takes to get the grain to an export position. The price forecasts are used as sample information and their accuracy is used to determine the probabilities that the price of durum will increase, decrease or not change during these thirteen weeks. The probability of each price movement will affect the decision of what quantity to forward price. The decision with the highest expected value is chosen as the optimal decision for each of the models. Then the revenues from these decisions, had they been carried out, are compared to see if the weather information had an impact on the revenue from forward pricing a portion durum wheat sales.

5.2 Conclusions

The analysis of the price forecasting models lead to the following observations and conclusions. The analysis of the estimated parameters of the market model showed that the year to year changes during the spring and summer contain information that is useful in predicting durum prices from one year to the next during the weeks after harvest. The price change that is predicted after harvest for durum by the market model is less than the combined price change of the spring months used in the forecast. The analysis of estimated parameters for the perfect weather model showed the change in durum supplies had the greatest effect on post harvest prices in late May and early June. Durum supply information in late June, July and August is less important in forecasting durum prices from mid September to November. This suggests that the durum market already reflects the supply information that will affect durum prices afer harvest.

An average price change in the spring or summer will have a greater effect on post harvest prices of durum than an average change in yearly durum supply. Therefore supplies tend to be more stable from year to year and presumably the primary factors causing prices to change were government programs and export demand.

The following observations and conclusions come from the decision analysis results. The weather models that allowed the decision maker to change forward contracting quantities each week were useful in determining the optimal decision when a price increase or decrease is forecasted. When no change in price is forecasted and a reversal of the marketing strategy is recommended the decision maker should examine the expected values of each decision. The expected values of each decision alternative are very close when no change in price is forecasted and therefore changing the marketing strategy used consistently throughout the year to date may not be necessary.

Forward contracting without weather information added value to the marketing of durum over the option of not forward contracting any grain. The weather information that allowed the decision maker the flexibility to change the quantities forward contracted each week with little risk of over selling added more value to the marketing of durum. On average the use of weather information in the determination of a marketing strategy adds value to the marketing of durum.

5.3 Limitations and Suggestions for Future Research

The drought index used to predict the production for each crop year was derived from only eight weather stations. There are many more weather stations in western Canada and North Dakota that could have been used to get a more accurate production prediction from the drought index. This may have improved the predictive power of the models that used the drought index information by bringing forecasted supply closer to the actual supply.

The drought index only uses weather information from North America to forecast production. Therefore only the supply information is used in the price forecasts. However, supply fluctuations in Europe and North Africa also may affect the price durum.

This study only examines the effects that the North American supply of durum has on the price of durum, not the demand for North American durum.

This study examines the value of weather information by studying how much extra revenue weather information can add to a large seller of durum wheat, such as the Canadian Wheat Board. However, weather information can also add value to the operations of the Canadian Wheat Board by significantly reducing the uncertainty about the size of an upcoming harvest. This reduces the risks involved in forward contracting a certain quantity of grain and forward contracts reduce the risk of price uncertainty.

Weather information is not only pertinent information to the size of a crop, but also to the quality of a crop. Excess moisture can significantly reduce the quantity of top grade grain. Weather information that allows the seller to know with confidence the quality of grain that will be available to sell has value. If the seller knows they will have a large quantity of high quality grain available to sell they can extract a premium for this high quality grain. If this information were not available and the seller forward contacted a large quantity of top quality grain that could not be delivered, the seller would be penalized. Thus, more research is required to determine the value of weather information with respect to the uncertainty of grain quality.

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Table A.1 Drought Indices by Week

Year	Week of the Year 23	24	25	26	27	28
1980	42.08	41.67	41.19	40.64	40.3	39.93
1981	48.41	49.13	49.73	50.15	50.44	50.68
1982	49.6	49.5	49.26	48.79	49.78	50.69
1983	48.1	47.61	47.07	46.44	46.87	47.49
1984	45.96	45.71	45.37	44.96	44.19	43.21
1985	47.75	47.55	47.21	46.75	46.03	45.03
1986	50.86	50.34	49.64	48.82	48.58	48.84
1987	48.43	47.42	46.33	45.52	46.32	47.16
1988	43.55	41.71	39.95	38.1	37.33	36.77
1989	47.24	47.29	47.26	47.15	46.85	46.5
1990	48.16	48.04	47.82	47.49	46.35	49.11
1991	51.66	52.56	53.1	53.32	53.47	53.73
1992	49.11	48.71	48.18	47.56	47.11	48.41
1993	46.87	47.67	48.38	48.96	51.9	55.12
1994	52.86	53.4	53.82	54.13	54.16	54.19
1995	49.1	49.01	48.85	48.68	48.7	48.79

Year	Week of the Year 29	30	31	32	33	34
1980	40.57	40.73	40.92	41.09	41.27	41.46
1981	50.94	51.2	51.02	50.68	50.38	50.11
1982	51.63	52.58	53.06	53.22	53.39	53.58
1983	48.17	48.76	48.84	48.36	47.94	47.62
1984	42.27	41.38	40.67	40.48	40.31	40.16
1985	44.05	43.07	42.18	42.35	42.46	42.77
1986	50.62	51.72	52.83	52.97	52.95	52.94
1987	48.02	48.9	49.29	49.51	49.76	50.01
1988	36.26	35.76	35.48	35.46	35.46	35.45
1989	46.17	45.83	45.5	45.27	45.05	44.89
1990	50.33	51.59	52.67	52.52	52.37	52.24
1991	53.97	54.17	54.31	54.1	53.86	53.63
1992	49.86	51.38	52.7	53.22	53.55	53.92
1993	58.18	59.39	59.32	59.29	59.02	58.34
1994	54.19	54.09	53.95	53.92	53.89	53.88
1995	48.87	48.95	49	48.91	48.83	48.76

Table B.1 Revenues from Weekly Exports (millions of US$) and the Direction of the Price Forecasts, (Price Increase = + Price Decrease = - No Change = nc)

1980								
Week	Market Model		Perfect Weather Model		Current Weather Model		One Wk Weather Model	
	Millions of US$							
36	10.7	+	11.3	+	11.3	+	11.3	+
37	10.7	+	11.3	+	11.3	+	11.3	+
38	10.6	+	11.2	+	11.2	+	11.2	+
39	11.9	+	12.2	+	12.2	+	12.2	+
40	11.7	+	11.8	+	11.9	+	11.9	+
41	11.5	nc	11.7	nc	11.7	nc	11.7	nc
42	12.3	nc	12.1	nc	12.4	nc	12.1	nc
43	12.4	+	12.0	+	12.0	+	12.0	+
44	11.9	+	11.7	+	11.7	+	11.7	+
45	11.8	nc	11.7	nc	11.7	nc	11.7	nc
46	11.7	nc	11.7	nc	11.7	nc	11.7	nc
47	11.9	nc	12	nc	12.1	nc	11.7	
Total	139.1		141		141.2		140.5	

1981								
Week	Market Model Model		Perfect Weather Model		Current Weather Model		One Wk Weather Model	
	Millions of US$							
36	11.1	nc	11.5	nc	11.5	nc	11.5	nc
37	11.2	nc	11.5	nc	11.5	nc	11.5	nc
38	10.9	+	10.6	+	10.6	+	10.6	+
39	10.9	nc	11.2	nc	11.2	nc	11.2	nc
40	10.9	nc	11.0	nc	11.0	nc	11.0	nc
41	10.8	nc	11.0	nc	11.0	nc	11.0	nc
42	10.8	nc	10.6	-	10.6	-	10.6	-
43	10.9	nc	10.9	nc	10.6	-	10.6	-
44	11.3	+	11.1	+	11.1	+	11.1	+
45	10.8	+	10.8	+	10.8	+	10.8	+
46	10.7	+	10.7	+	10.6	+	10.6	+
47	10.4	nc	10.2	+	10.7	nc	10.2	
Total	130.7		131.1		131.2		130.7	

Table B.1 (Continued)

1982								
Week	Market Model		Perfect Weather Model		Current Weather Model		One Wk Weather Model	
			Millions of US$					
36	10.4	+	10.0	+	10.0	+	10.0	+
37	10.3	+	9.8	nc	9.8	+	9.8	+
38	10.1	+	10.6	nc	10.4	nc	10.4	nc
39	10.2	nc	10.5	nc	10.4	nc	10.4	+
40	10.1	nc	9.9	nc	9.9	nc	9.9	nc
41	10.1	nc	10.3	nc	10.2	nc	10.2	nc
42	10.3	+	10.1	+	10.1	+	10.1	+
43	10.2	+	10.1	+	10.1	+	10.1	+
44	9.9	-	9.9	-	9.8	-	9.8	-
45	10.1	+	10.1	+	10.1	+	10.1	+
46	10.3	+	10.2	+	10.2	+	10.2	+
47	10.4	+	10.3	+	10.3	+	10.3	
Total	122.4		121.8		121.3		121.3	

1983								
Week	Market Model		Perfect Weather Model		Current Weather Model		One Wk Weather Model	
			Millions of US$					
36	10.3	nc	10.2	+	10.3	+	10.3	+
37	10.5	nc	10.6	+	10.6	+	10.7	+
38	10.5	nc	10.4	nc	10.4	nc	10.4	nc
39	10.4	nc	10.4	nc	10.4	nc	10.4	nc
40	10.0	nc	10.0	nc	10.0	nc	10.0	nc
41	10.3	nc	10.3	nc	10.3	nc	10.3	nc
42	10.0	-	9.9	-	10.0	-	10.0	-
43	10.2	nc	10.0	-	10.0	-	10.0	-
44	10.2	nc	10.2	nc	10.2	nc	10.2	nc
45	10.5	+	10.3	+	10.3	+	10.3	+
46	10.6	+	10.2	+	10.1	+	10.1	+
47	10.2	nc	9.8	+	9.8	+	9.8	
Total	123.7		122.3		122.4		122.5	

Table B.1 (Continued)

1984								
Week	Market Model		Perfect Weather Model		Current Weather Model		One Wk Weather Model	
				Millions of US$				
36	7.5	-	7.8	nc	7.8	nc	7.8	nc
37	7.5	-	7.5	+	7.5	nc	7.5	nc
38	7.8	+	7.4	+	7.4	+	7.4	+
39	7.5	nc	7.3	+	7.3	+	7.3	nc
40	7.5	nc	7.3	nc	7.3	nc	7.3	nc
41	7.6	+	7.5	+	7.5	+	7.5	+
42	7.9	nc	7.6	+	7.6	+	7.6	+
43	7.4	nc	7.4	+	7.4	+	7.4	+
44	7.6	nc	7.4	nc	7.6	nc	7.6	nc
45	8.0	nc	7.6	nc	8.1	nc	8.1	nc
46	7.7	nc	7.5	nc	7.5	nc	7.5	nc
47	7.7	nc	7.5	+	7.5	+	7.5	
Total	91.7		89.8		90.5		90.5	

1985								
Week	Market Model		Perfect Weather Model		Current Weather Model		One Wk Weather Model	
				Millions of US$				
36	6.5	nc	6.1	nc	6.8	nc	6.7	nc
37	6.4	nc	6.4	nc	6.7	nc	6.7	nc
38	6.4	nc	6.5	nc	6.7	nc	6.7	nc
39	6.2	nc	6.2	nc	6.4	nc	6.3	-
40	6.2	nc	6.2	nc	6.3	nc	6.3	nc
41	6.2	nc	5.9	nc	6.4	nc	5.9	nc
42	6.0	-	5.9	-	6.0	-	6.0	-
43	6.1	+	5.9	+	5.9	+	5.9	+
44	5.9	nc	5.8	nc	6.0	nc	5.8	nc
45	5.8	-	5.9	nc	6.0	nc	6.0	nc
46	5.8	-	6.0	-	6.0	nc	6.0	nc
47	5.9	-	6.0	-	5.9	-	6.0	
Total	73.4		72.8		75.1		74.3	

Table B.1 (Continued)

	1986							
Week	Market Model		Perfect Weather Model		Current Weather Model		One Wk Weather Model	
			Millions of US$					
36	10.3	-	11.6	-	11.4	-	11.3	-
37	10.5	-	11.6	-	11.4	-	11.3	-
38	10.3	-	10.5	-	10.5	-	10.5	-
39	10.0	-	10.5	nc	10.4	nc	10.4	nc
40	10.2	-	10.3	-	10.3	-	10.3	-
41	9.9	+	9.8	+	9.9	+	9.9	+
42	10.4	+	10.3	+	10.3	+	10.3	+
43	9.9	+	10.2	+	10.3	+	10.2	+
44	9.9	nc	10.1	nc	9.4	nc	9.4	nc
45	10.1	+	10.3	+	10.3	+	10.3	+
46	9.9	+	10.0	nc	9.4	nc	9.4	nc
47	10.1	+	10.3	+	10.3	+	10.3	
Total	121.5		125.5		123.9		123.6	

	1987							
Week	Market Model		Perfect Weather Model		Current Weather Model		One Wk Weather Model	
			Millions of US$					
36	13.3	nc	13.6	nc	13.0	nc	13.1	nc
37	12.5	+	12.9	+	12.9	+	12.9	+
38	12.9	+	12.9	+	12.9	+	12.9	+
39	12.9	+	12.8	+	12.8	+	12.8	+
40	12.7	+	12.7	+	12.7	+	12.7	+
41	12.2	+	12.6	nc	12.7	+	12.6	nc
42	12.1	nc	12.6	nc	11.5	nc	11.4	nc
43	12.3	+	12.4	nc	12.4	nc	12.4	nc
44	12.4	+	12.5	+	12.5	+	12.5	+
45	12.7	+	12.6	+	12.6	+	12.6	+
46	13.0	+	12.9	+	12.9	+	12.9	+
47	13.1	+	13.0	+	13.0	+	13.0	
Total	152.1		153.5		151.9		151.8	

Table B.1 (Continued)

1988								
Week	Market Model		Perfect Weather Model		Current Weather Model		One Wk Weather Model	
			Millions of US$					
36	8.8	-	8.5	-	9.4	-	9.2	-
37	8.5	-	8.3	-	8.7	-	8.6	-
38	8.5	-	8.2	-	8.7	-	8.5	-
39	8.1	-	7.9	-	8.1	-	8.1	-
40	7.9	-	7.8	-	7.9	-	7.9	-
41	7.7	-	7.8	nc	7.9	nc	7.9	nc
42	7.5	nc	7.5	+	7.5	+	7.5	+
43	7.5	nc	7.5	+	7.5	+	7.5	+
44	7.3	nc	7.4	nc	7.4	nc	7.4	nc
45	7.3	nc	7.4	nc	7.3	nc	7.3	nc
46	7.3	nc	7.4	nc	7.4	nc	7.4	nc
47	7.3	nc	7.4	nc	7.3	nc	7.4	
Total	93.7		93.1		95.1		94.7	

1989								
Week	Market Model		Perfect Weather Model		Current Weather Model		One Wk Weather Model	
			Millions of US$					
36	14.3	-	14.2	nc	15.1	nc	15.1	nc
37	14.3	nc	13.9	+	14.9	nc	14.9	nc
38	13.8	-	14.6	nc	14.8	nc	14.8	nc
39	14.2	nc	14.6	nc	14.3	-	14.3	-
40	14.4	nc	14.9	nc	15.0	nc	15.0	nc
41	14.6	+	14.0	+	14.0	+	14.0	+
42	14.5	nc	14.0	nc	15.0	nc	15.0	nc
43	14.4	+	13.9	nc	14.8	nc	14.8	nc
44	14.1	+	13.5	+	13.5	nc	13.5	nc
45	13.8	nc	13.4	nc	14.3	nc	14.3	nc
46	14.0	nc	13.4	-	14.0	-	14.0	-
47	14.0	nc	13.4	-	14.0	-	13.4	
Total	170.4		167.8		173.7		173.1	

Table B.1 (Continued)

1990								
Week	Market Model		Perfect Weather Model		Current Weather Model		One Wk Weather Model	
	Millions of US$							
36	12.0	-	13.3	-	13.0	-	12.9	-
37	12.1	-	13.4	-	13.0	-	13.0	-
38	12.0	-	13.0	-	12.7	-	12.6	-
39	11.8	-	12.6	-	12.3	-	12.3	nc
40	12.2	nc	12.5	-	12.8	nc	12.8	nc
41	11.8	-	12.3	-	12.2	-	12.2	-
42	11.9	nc	11.4	-	12.4	nc	12.0	-
43	11.8	nc	11.3	-	11.9	-	12.0	-
44	11.1	-	10.9	-	11.3	-	11.3	-
45	11.3	nc	11.0	-	11.0	-	11.0	-
46	11.2	nc	11.0	nc	11.5	nc	11.5	nc
47	11.1	nc	10.8	nc	11.7	nc	10.8	
Total	140.3		143.5		145.8		144.4	

1991								
Week	Market Model		Perfect Weather Model		Current Weather Model		One Wk Weather Model	
	Millions of US$							
36	11.5	-	11.7	-	11.7	-	11.7	-
37	11.7	-	11.7	-	11.7	-	11.7	-
38	11.9	-	11.6	-	11.6	-	11.6	-
39	12.2	-	12.0	nc	12.0	nc	12.0	nc
40	12.4	nc	12.1	nc	12.1	nc	12.1	nc
41	12.5	nc	12.8	+	12.8	+	12.8	+
42	12.1	+	12.3	nc	11.6	nc	11.6	nc
43	12.5	nc	12.8	nc	11.7	nc	11.7	nc
44	12.5	nc	12.8	+	12.8	+	12.8	+
45	12.6	+	12.9	+	12.9	+	12.9	+
46	12.4	+	12.5	+	12.5	+	12.5	+
47	12.5	+	12.6	nc	12.2	nc	12.6	
Total	146.8		147.8		145.6		146	

Table B.1 (Continued)

	1992							
Week	Market Model		Perfect Weather Model		Current Weather Model		One Wk Weather Model	
	Millions of US$							
36	9.6	-	10.1	nc	9.6	+	9.6	+
37	10.0	nc	9.9	nc	9.9	+	9.9	+
38	9.9	nc	9.8	nc	9.7	nc	9.7	nc
39	9.9	nc	9.8	+	9.8	+	9.8	+
40	9.6	+	9.5	+	9.4	+	9.4	+
41	9.6	+	9.5	+	9.5	+	9.5	+
42	9.2	nc	9.2	nc	9.2	nc	9.2	nc
43	9.3	+	9.2	+	9.2	+	9.2	+
44	9.5	+	9.4	+	9.4	+	9.4	+
45	9.4	+	9.5	+	9.5	+	9.5	+
46	9.1	nc	9.2	nc	8.8	nc	8.8	nc
47	9.1	nc	9.3	+	9.3	+	9.3	
Total	114.2		114.4		113.3		113.3	

	1993							
Week	Market Model		Perfect Weather Model		Current Weather Model		One Wk Weather Model	
	Millions of US$							
36	12.5	+	13.2	+	13.3	+	13.3	+
37	12.6	+	13.1	+	13.3	+	13.3	+
38	12.4	nc	13.0	nc	13.1	nc	13.1	nc
39	12.5	nc	13.0	nc	13.1	+	13.1	+
40	12.6	nc	11.4	nc	11.7	nc	11.5	nc
41	14.4	nc	14.6	+	14.7	+	14.6	+
42	14.5	nc	14.6	+	14.6	+	14.6	+
43	15.1	nc	15.4	+	15.3	+	15.3	+
44	15.0	+	15.4	+	15.4	+	15.4	+
45	15.2	+	15.6	+	15.6	+	15.6	+
46	16.7	+	17.5	+	17.4	+	17.4	+
47	16.6	+	17.2	+	17.1	+	17.2	
Total	170.1		174		174.6		174.4	

Table B.1 (Continued)

1994								
Week	Market Model		Perfect Weather Model		Current Weather Model		One Wk Weather Model	
			Millions of US$					
36	21.8	+	21.5	nc	21.5	nc	21.5	nc
37	20.7	+	20.7	+	20.6	+	20.6	+
38	21.6	+	22.3	+	22.3	+	22.3	+
39	21.8	+	22.8	+	22.7	+	22.7	+
40	21.8	+	22.6	+	22.5	+	22.5	+
41	22.1	+	22.7	+	22.6	+	22.6	+
42	23.4	+	23.2	+	23.2	+	23.2	+
43	23.5	+	23.2	+	23.1	+	23.1	+
44	23.1	+	23.0	+	23.0	+	23.0	+
45	22.2	+	22.8	+	22.7	+	22.7	+
46	21.8	+	22.0	+	21.9	+	21.9	+
47	21.7	+	22.0	+	21.9	+	22.0	
Total	265.5		268.8		268		268.1	