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Structural Change of the Western United States Alfalfa Hay Market and Its Effect on the Western United States Dairy Industry

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STRUCTURAL CHANGE OF THE WESTERN UNITED STATES ALFALFA HAY MARKET AND ITS EFFECT ON THE WESTERN UNITED STATES DAIRY INDUSTRY

by

Joseph Cann

A thesis submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Applied Economics

Approved:

Donald Snyder Major Professor	Dillon Feuz Committee Member
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UTAH STATE UNIVERSITY
Logan, Utah

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ABSTRACT

Structural Change of the Western United States Alfalfa Hay Market and its Effect on the Western United States Dairy Industry

by

Joseph Cann, Master of Science

Utah State University, 2014

Major Professor: Dr. Donald Snyder
Department: Applied Economics

Alfalfa is the fourth largest commodity grown in the Western U.S., representing 20% of the crop acreage over the past twenty years. In the last five years alfalfa hay price has doubled from what it was previously, indicating a possible structural change in the market. This research project was completed to test for this structural change using econometric analysis of the important demand components of alfalfa price. In addition to this, simulations of an average Utah dairy were completed to examine which ratio of forage crops provided the highest economic return to the operation.

To analyze the structural change of the alfalfa hay market milk price, feeder price, commodity price, dairy inventory, alfalfa ending stocks, alfalfa exports, a structural shift dummy variable, and two proxy variables representing costs and quality were regressed, explaining 76% of the variation in alfalfa hay price. A Chow-test of the divided data set provided evidence that a structural change occurred in the alfalfa hay market circa 1994. Percent changes in the independent variables and corresponding changes in alfalfa price were calculated, showing that milk price has the largest influence over alfalfa price. An in-sample forecast showed that the regression was able to predict alfalfa hay price to within an average of $14 of the actual price over the timeframe included in the analysis.

The simulation of an average Utah dairy was done at three levels of production: 18,300 lbs, 22,500 lbs., and 26,700 lbs. production. Within each level of production the alfalfa to corn silage ratio was varied to represent 25/75, 50/50, and 75/25%, respectively, of the dry matter forage requirement. It was found that return to management was the greatest when alfalfa was 25% of the ration and at the lowest when alfalfa was 75% of the ration at all levels of production.

(104 pages)

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(104 pages)

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Joseph Patrick Cann

CONTENTS

LIST OF TABLES

Table Page

LIST OF FIGURES

Figure Page

CHAPTER 1

INTRODUCTION

Alfalfa hay is an important crop grown in the Western United States. In this region over the past twenty years alfalfa hay has consistently utilized 20% of crop acreage. Alfalfa hay had a value of 4.8 billion dollars in 2012 (USDA 2013), making it the 4th largest commodity produced in the West (Putman et al. 2000). In spite of this, relatively few studies have been done on alfalfa hay markets.

In a study published by Blake and Clevenger (1984), they stated that "No published studies to forecast alfalfa hay prices were found. Although an important input in beef, dairy and horse production, alfalfa hay price forecasting has received scant attention in the literature." Shortly after Blake and Clevenger published their study, Sorenson (1985) described the hay marketing system this way,

> "Hay marketing remains almost primitive. It is traded farmer-to-farmer, farmer-to-dealer, or farmer-to-trucker. There is no national market, no uniform quality standards, no countrywide communications network for hay."

While a uniform quality standard was established in 1945 by the USDA, and updated since then (USDA 2002), much remains the same today with the relationships between farmers, dealers, and truckers. Due to the availability of local hay directories and publications on the internet, what limited information that exists on alfalfa prices is more widely distributed, but not much else has changed.

The alfalfa hay market is made up of large numbers of producers (or sellers) and buyers. Demand has primarily been the U.S. livestock market, with the dairy industry requiring sizable quantities of high quality forage. Konyar and Knapp (1988) estimated that 65% of California alfalfa was fed to dairy cows, 18% was consumed by beef cattle and 17% by horses and other livestock. One of the challenges associated in analyzing the alfalfa hay market, for structural change and forecasting purposes, is that much of the alfalfa grown on farms in the region is fed to animals on the same operation and never enters the commercial hay market.

While the number of animals in the U.S. livestock industry has remained relatively static, alfalfa exports have increased over the last 30 years. The Western U.S. accounts for 99% of alfalfa hay exports (Putman et al. 2012). On a total alfalfa production basis, exports represented only 1.7% of total alfalfa production in 1980, whereas exports were 4.2% of alfalfa production in 2012, a 4 fold increase. The export market is even more significant when the structure of the hay market is taken into account. As noted above, a major proportion of alfalfa hay produced never enters the market because it is grown by livestock producers and fed to their own animals. This is represented by the difference between the total value of the alfalfa hay produced and the amount recorded in the USDA cash receipts report. So, if it is assumed that the amount recorded in the USDA cash receipts represents the total volume of hay in the commercial market, exports have gone from 1.7% in 1980 to 29.9% in 2012 of Western U.S. cash sales, a significant increase (USDA-FAS 2014).

Exports are primarily driven by demand in mature markets such as Japan, South Korea, and Taiwan, as well as emerging markets in China and United Arab Emirates (UAE). The demand from China alone has increased from 2,000 metric tons (MT) in

2007 to 76,000 MT in 2009. China is the world's third largest dairy producer with 12.8 million dairy cattle (Chen 2009). The USDA estimated that Chinese demand could be as high as 20 million tons yearly if each dairy cow were to consume 11 pounds of alfalfa a day, but its current production capacity was only 4.6 million tons annually. Chinese growers are capable of growing the needed forage but as other commodity prices have increased they have switched production into these other markets (Chen 2009). Water conservation has been the driving force behind increased forage imports into the Middle East. Saudi Arabia plans to completely phase out forage production by 2016, and the UAE government is supporting forage imports for non-commercial, as well as commercial, livestock owners. U.S. alfalfa exports are facing increased competition from Spain and Australia, but exports should continue to grow because of the high quality available in the U.S. relative to these other countries (Wilhelm 2010).

With the increase in exports the Western U.S. alfalfa hay market is experiencing, it is hypothesized that the market has experienced a structural change in demand. *The New Palgrave: A Dictionary of Economics* (Eatwell, Milgate, and Newman 1987) defines structural change "as a change in the relative weight of significant components of the aggregative indicator of the economy such as national product and expenditure, exports and imports, and population and the labour force." Goddard et al. (1993) stated that "in order to be structural change, the change in composition of the aggregate indicators for the organizations or institutions must be permanent and irreversible rather than a transitory or reversible change that may result from temporary scarcities or temporary exogenous shocks."

Past studies do not take into account the increasing export market, nor the pressure being applied to growers with options to increase profits by growing crops other than alfalfa. Structural change has also been neglected in the available agricultural literature, the only references found that the primarily focus was structural change was focused on the increasing size of farms (Schertz 1979, Goddard et al. 1993). A publication by Myer and Yanagida (1984) was one of the few exceptions found. They looked at the oil embargo and increased grain trade with Russia in 1973 and found evidence of structural change in the alfalfa hay market at that time.

Fundamental changes in the demand for alfalfa hay, such as increasing hay exports, has the potential to keep upward pressure on alfalfa hay prices for many users in the years to come. This particularly represents a problem in the dairy industry where large milk price fluctuations routinely place stress on the industry and an understanding of these changes is vital. This research paper will look at the increase in alfalfa exports and other commodity prices to determine if a structural change has occurred. If alfalfa hay exports continue to increase as expected, with exports currently comprising 30% of cash sales, dairy producers will need to evaluate what proportion of alfalfa to include in their ration so as to achieve the maximum economic benefit. This is the main focus of the second portion of this study.

Alfalfa hay is one of two crops primarily used as forage for Western U.S. dairies (Robinson 2014), the other being corn silage. It has even been suggested that the availability of high quality alfalfa hay originally allowed the dairy industry to become established in California (Robinson 1998). The debate has been ongoing over an extended period of time regarding which is the better forage component for increased milk production. The literature extensively covers which forage source improves milk and milk component production. The consensus appears to be that both forages, when properly used in the ration, will fulfill the nutritional requirements of dairy cows, but there are wide ranging analyses on the economic costs and benefits of hay and corn silage in the ration. The non-consensus regarding the economics of the correct combination of alfalfa hay and corn silage is in part due to the wide range and fluctuations of milk prices and feed costs facing the dairy industry.

Holter, Johns, and Urban (1975) found alfalfa and corn silage were the same in terms of milk production when fed in equivalent amounts of dry matter (DM). Belyea et al. (1975) found similar results, but added that animals fed equivalent amounts of DM had similar feed intakes and ending body weights. Grieve et al. (1980) examined how health was affected by ratios of corn silage and alfalfa. It was found that incidence of health problems was not outside of normal ranges regardless of the feed mixture. Additionally, metabolic diseases and reproduction were not affected. The same year Grieve et al. (1980) also found that milk composition and solids-corrected milk yield per unit of DM intake were unaffected by different ratios of alfalfa and corn silage. Erdman, Piperova, and Kohn (2011) found no advantage to milk production when alfalfa was included in a corn silage based ration.

Rankin (2000) said

> “Just as they (alfalfa and corn silage) are in an agronomic sense, alfalfa and corn silage complement each other from a nutritional perspective. Although both

> provide the needed fiber components of milk cow rations, corn silage is high in energy, whereas alfalfa is high in protein."

Shaver, Satter, and Jorgensen (1988) agreed by stating "combining corn silage and alfalfa in dairy rations at moderate rates helps minimize deficiencies or excesses that may result from feeding either forage at a very high rate or as the sole forage." Dhiman and Satter (1997) suggested corn silage should make up one-third to two-thirds of dietary forage DM and alfalfa hay the remainder. The suggested ratio of corn silage to alfalfa hay in the ration of one-third to two-thirds is a very broad range resulting in the same milk production and animal welfare (Dhiman and Satter 1997).

The decision on what ratio best fits an individual farm operation should be determined by factors affected by location and individual farm management practices such as: 1) whether the climate in which the farm operates is conducive to grow a high quality of each forage consistently, 2) what dry matter yield per acre historically is achieved by each farm, 3) what the stand life is for alfalfa, 4) how much acreage is available, 5) what is the availability and size of machinery complement, and 6) how much labor is available during the harvesting window. These six criteria outline the economic interaction between the production costs of alfalfa and corn silage and maximizing the return from milk production.

Due to the complexity of the questions asked and the multiplicity of factors involved, a whole farm economic model will be used to evaluate what the most economical ratio of forage is that can be incorporated in an average Utah dairy operation. This has been done previously for Michigan dairies (Borton et al. 1997). They acknowledged, “Previous studies have shown that one forage is not always better than the other using economic criteria.” Additionally they noted, “Feeding trials generally demonstrate similar milk production from cows fed diets based on either corn or alfalfa silage when the rations are properly balanced.” They used The Dairy Forage System Model (DAFOSYM) to model this complex process on Michigan dairies to determine the best alfalfa and corn silage forage ratio. They concluded that it was best to use a minimum of one-third of each crop in the ration to fulfill the forage DM requirement and that the use of more than one forage crop reduced the risks associated with crop failure and spread labor requirements more uniformly across the harvesting season. The multiple forage systems modeled using DAFOSYM also better utilizes on-farm nutrients through optimal manure application.

This study will perform the same analysis on a Utah dairy using the Integrated Farm System Model (IFSM), the newest version of DAFOSYM, which is available from the Agricultural Research Service (Rotz and Coiner 2004). Since corn silage and alfalfa can be interchanged in the ration without negative effects to milk production or animal health, the question of which feed to use is centered on the economics and risk of forage production. Weather is the major factor attributed to production risk and has major implications for forage production. IFSM simulates all major farm components on a daily process level using historical weather data. Crop production, subsequent storage and use to produce milk, and the return of manure nutrients back to the land are simulated over a minimum of twenty five years using historical weather data. This simulation of forage quality, crop growth and development are predicted on a daily time frame based on water and nutrient availability, ambient temperature, and solar radiation. Feed allocation is formulated using a cost-minimizing linear programming approach. Simulated crop production is used to determine production costs, incomes and economic return using long range estimated prices for each year simulated. This is incorporated into a whole-farm budget to determine a net return to the herd and management.

The six location and management factors affecting the ration forage mixture outlined above will be address for an average Utah dairy by the IFSM model. The quality of forage will be simulated over 25 years. This will provide information on how much corn can be grown and the quantity and quality of alfalfa grown. DM forage yield will be simulated by the model to project average production yield and costs per acre. IFSM allows us to select average stand life for alfalfa. This represents how long a grower will allow alfalfa to grow before it is removed from production. Acreage was estimated based on DM requirements of average dairy cow and replacement heifer (the process by which this was done is outlined in the methodology chapter). The results will show if the acreage requirements change at different levels of production. Machinery and labor requirements are included in the model and assumed to be adequate. Both will remain constant across all simulations.

The goals of this research project are to identify weather changes in the alfalfa market have occurred, and if so, determine what ratio of alfalfa hay and corn silage should be grown and fed on an average Utah dairy farm. Specific objectives are to: 1) identify if any structure change in the alfalfa hay market has occurred, 2) determine which components of demand are influencing the change in alfalfa price and in what magnitude, 3) evaluate the financial performance of the average Utah dairy operation when alfalfa hay represented A) one-third, B) one-half and C) two-thirds of the forage DM in the dairy ration, with corn silage representing the remainder, and 4) evaluate the differences the effects these three rations will have on the economic and financial performance of the operation at three levels of production.

Ordinary least squares regression analysis will be used to examine the alfalfa hay market, with the Chow-test being the test chosen method that will be used to examine for structural change of the market. The Integrated Farm System Model from the USDA will be used to simulate the average dairy farm over a twenty five year period. This model allows us to do a process level simulation to examine total cost or benefit when one process is changed and the rest are held constant.

The following chapters will include: Chapter 2, past research of the two areas examined in this Dissertation, Chapter 3, the underlining theory of the model, Chapter 4, methods and data used in the regression analysis of the alfalfa hay market, Chapter 5, methods and data used in the simulation of an average Utah dairy operation, Chapter 6, results of the regression analysis and the simulation, and Chapter 7, conclusion and recommendations for further research.

CHAPTER 2

LITERATURE REVIEW

Since two different subjects are being addressed in this literature review, a review for each is given in the following two sections. First, articles related to the alfalfa hay market will be discussed. Second, relevant studies on how the dairy industry has evaluated the choice between alfalfa and corn silage in the ration fed will be addressed.

Alfalfa Hay Market

Even though alfalfa hay is a major crop grown in the western United States, a minimal amount of research and information is available on the subject. Blake and Clevenger (1984) worked to develop a forecast that would help producers ascertain a starting price for their crop before the first cutting of the year. They forecast the initial price of new alfalfa hay in May. They then identified the seasonal price pattern using ordinary least squares (OLS) based on data from 1960 to 1982. To forecast the initial price, they estimated alfalfa production as a function of the previous year crop acreage. Production was then combined with the April 1 price of a September corn futures contract, plus a time variable, to find the May price. Blake and Clevenger noted that there were no published studies on the alfalfa hay market or any previous forecasts developed, though they acknowledged Myer and Yanagida (1984) were in the process of developing their own forecasting study at the same time.

Myer and Yanagida (1984) evaluated an ad hoc procedure of combining econometric and an autoregressive integrated moving average (ARIMA) price forecasting models for alfalfa hay. The econometric model was based on eleven western states using a wholesale price index, hay production, price of other hay, annual corn price, a farm labor wage index, the January 1 inventory of cattle, a farm productivity index and an intercept shifter to test for structural change in 1973. The ARIMA model used seasonal autoregressive and moving average parameters for the time period 1953-78. They acknowledged serial correlation was a problem in the model. The intercept shifter was significant, supporting the hypotheses that a change had happened in the market at the hypothesized time.

Blake and Catlett (1984) looked at cross hedging alfalfa hay using corn futures. They noted that outside of forward contracting, there was no mechanism to shift the risk of price variation to the hay consumer. They focused on monthly New Mexico and U.S. average alfalfa hay prices in relation to Chicago Board of Trade corn futures prices. They found that May was the best corn futures contract to use hedging 38-47 tons per contract. Using simulation, they also found that cross hedging hay with corn futures increased gross returns for U.S. and New Mexico hay producers.

In an assessment of hay market institutions and coordination functions, Miller (1986) found there were three distinct sub-markets within the overall alfalfa hay market: the dairy and cattle market, the fancy horse market and the damaged hay market. There were also regional differences. He indicated that the market was based on trust and that 7 out of 34 surveyed sellers had experienced nonpayment for hay delivered. This problem was also implied in Hoyt's (2006) report of the associated risk suppliers of hay to dairies face when dairies were operating in the red.

Konyar and Knapp's (1988) published an article titled "Market Analysis of Alfalfa Hay: California Case," which was one of the most cited articles found. While looking at the indirect impact of government programs, they developed four econometric and ARIMA acreage response models, an alfalfa demand model and an econometric price forecast model. It was found that alfalfa hay acreage responded to changes in competing crop prices, cattle inventory, cost of production, its own price, and, indirectly, by government programs. Multicollinearity was identified as a problem in the econometric analyses by the authors. Elasticity of substitution between hay acreage and competing crops was found to be low, suggesting that changes in competing crop prices had little effect on hay acreage.

Skaggs (1989) thesis looked at quarterly and monthly forecasts of alfalfa and feeder cattle, generated from 1980 through 1986, using nine independent alternative quantitative forecasting procedures (classical decomposition, Holt-Winters exponential smoothing, Box-Jenkins univariate stochastic, bivariate stochastic or transfer function analysis, vector autoregression, multiple regression, and a simultaneous structural system). Results of the forecast evaluation procedures demonstrated the extent to which the type of error (i.e., absolute error vs. turning point error) or source of error (bias, actual variance, forecast variance, or actual and forecast covariance) could be traded off against each other. The problem of the conflicting results produced by the selected valuation criteria was shown to diminish when the results were addressed from the standpoint of the end-user. No one forecasting technique was identified as a clear winner with respect to predictive ability.

Konyar and Knapp (1990) estimated acreage response functions for 25 regions of the California alfalfa hay market. Using the estimated functions, they found long-run equilibrium acreage and price. It was suggested that alfalfa acreage was most sensitive to production costs in the short run and livestock feed costs in the long run. Acreage was also affected by yield increases. Finally, it was found that changes in water rates and government cotton subsidies affected alfalfa hay acreage.

Skaggs, Gorman, Gardner, and Crawford (2002) examined the potential of New Mexico to grow its dairy herd because of a perceived limitation on the availability of alfalfa hay. From a survey of alfalfa and dairy producers, it was suggested that the growth of the dairy industry would not be affected because dairies only consumed 27% of the state's hay production and that they were not totally dependent on New Mexico hay. Even with a 50% increase in the dairy herd, it was estimated sufficient hay would be available.

In discussing market outlook, Hoyt (2006) stated there were four factors that had a major impact on hay supplies and prices: hay carryover, hay acres in 2011, milk price, and hay exports, with a possible fifth factor of corn silage supply. He noted that hay growers in 2011 would have more options for their acreage than in years past with high prices in the corn, wheat, and cotton futures markets.

Bazen et al. (2008) econometrically modeled the factors affecting hay supply and demand in Tennessee. Factors that were modeled in the supply functions were: hay, wheat, seed, fertilizer prices, rainfall, lagged hay acres and percent change of Tennessee row-crop acreage. Demand was modeled with hay production, soybean price, per capita income for Tennessee, December 31 cattle inventory, and a time trend. Changes in alternative crops prices, input prices, and weather showed relatively small effects on hay production and prices. They assumed this was because many hay producers were also cattle producers who harvested their own hay to maintain a reliable source of forage. In addition, they found that changes in the Conservation Reserve Program (CRP) program would not significantly affect price and production of alfalfa hay.

Diersen (2008) developed a balance sheet model for South Dakota to better model alfalfa hay price changes within a marketing year and from one marketing year to the next. Supply was modeled as a function of expected acres which were derived from a function of last year's acreage, December hay price, May harvest price and a time trend to account for yield increases. Demand was modeled as a function of price, December stocks, fall use, May stocks and winter use. Functions for each supply and demand component were derived. It was found that the demand equations explained more of the variability in hay price than the supply equations.

Gray (2010) computed a seasonal price index for five different qualities of Idaho alfalfa hay. The indexes revealed there were seasonal fluctuations in hay price. He found the highest prices for the season occurred July through September for all qualities of hay and were lowest in April, just before the new crop was harvested.

Gombos (2011) analyzed the effects of population growth and resource scarcity and how they would shape and refine the relatively new forage export industry in the United States. While there were mature markets in Japan, South Korea and Taiwan, new markets were opening up in China and the Middle East. In China alone, hay imports doubled each year from 2005 to 2010. New areas of supply are also coming opening up due to the increased demand. Whether or not the Western U.S. will remain the dominate source of forage for the export markets will depend on if producers can keep costs low and a readily available supply of product.

Dairy Industry

One of the objectives of this research project is to evaluate the financial performance of a dairy operation when corn silage replaces alfalfa hay in the ration. There are primarily three questions to ask when making these changes. First, what is the animal performance under the two rations? Second, what process interactions are going to change on the operation when forage systems are changed? Third, how is this going to affect the overall financial standing of the dairy?

The first question regarding animal performance has been examined in depth and relevant studies are presented below. The second and third questions have been addressed, but not to the same extent as the first and none were found at all for the Western U.S. dairy herds, which have different aspects than in the Midwest and East.

Holter, Johns, and Urban (1975) performed an experiment in which first lactation Holstein heifers were fed four different rations of corn silage and alfalfa silage. Milk yield and dry matter (DM) intake were measured. They found no significant difference between the rations from either a milk production or DM intake perspective.

Belyea et al. (1975) compared DM intake, production, and body weight over three lactations to evaluate corn silage, alfalfa hay and alfalfa silage. One group was fed corn silage and alfalfa hay, the second corn silage and alfalfa silage, and a third just corn silage. Milk production, DM intake and body weight did not differ significantly among the treatment groups over the three lactations. They postulated that animals fed corn silage and alfalfa silage as a mix would reduce the amount of protein supplementation required and provide a more uniform intake of nutrients from forage. They found the corn silage-alfalfa silage mix did provide a more uniform intake, but that alfalfa was not required in the ration with long term corn silage feeding.

Grieve et al. (1980) fed three groups of Holstein heifers, from birth through three lactations, three rations consisting of only corn silage, corn silage and alfalfa silage in a 60:40 ratio and corn silage and alfalfa hay in a 40:60 ratio. They tracked overall health, survivability, and reproduction. Health problems and reproduction rates were within normal ranges across all treatments. They concluded corn silage could be fed alone without long term adverse effects on health and reproduction. They also found that both groups of cows fed the corn silage/alfalfa hay ration consumed the most forage DM in each period measured, except in the second lactation. This difference, over the third group, was greatest in the first lactation. Milk and solids-corrected milk yields were lower for animals fed corn silage alone in the first two lactations. These results were different than earlier studies and it was assumed that some of the effects from the feeding program occurred when the animals were very young and carried over into the lactation period. Feeding animals these rations from birth through the third lactation had never been done before.

Dhiman and Satter (1997) fed 74 Holstein cows three different ratios of alfalfa silage and corn silage for 36 weeks of lactation. The ratios were 1) all alfalfa silage, 2) two-thirds alfalfa silage, and one-third corn silage; 3) and one-third alfalfa silage and two-thirds corn silage. DM intake and milk production was highest for cows fed one-third corn silage. They found that there was a small economic benefit of incorporating corn silage as one-third of the ration when protein utilization, labor distribution and risk of crop failure were taken into account.

Borton et al. (1997) used a whole farm simulation model called Dairy Forage System Model (DAFOSYM) to ascertain the relative merits of corn silage and alfalfa when these two feeds were varied in the ration. They simulated the economic and financial benefits attributable to feeding alfalfa and corn silage in four simulations: 100% alfalfa; one-third corn silage and two-thirds alfalfa; two-thirds corn silage and one-third alfalfa; and 100% corn silage as total forage DM. A whole farm approach was taken because of the previous findings that the practice of feeding different rates of the two forages didn't have any impact on milk production, so overall farm performance and economics became the key issues for forage selection. The simulation was based on a 120 lactating and dry cow Michigan dairy operation. The acreage required varied from 132 to 162 hectares (or a difference of 74 acres) depending on the forage ration. They found little difference between forage systems and recommended that a forage production system contain at least one-third of each forage.

Harsh, Wolf, and Wittenberg (2001) undertook the task of assessing different segments of a diversified dairy operation, namely crop production, cost of raising replacement heifers, and milk production. Enterprise accounting methods were used based on eight Michigan dairies. They found that 1) the average cost of production was almost equal to the average milk herd revenue per hundredweight, 2) all farms included in the study covered variable costs of milk production, 3) five of the eight dairies showed profits when all costs of production were included and 4) all six farms that raised their own heifers lost money on the enterprise. The analysis of crop production showed that grain corn and corn silage were not profitable enterprises, but hay was profitable for five of the farms.

Allen (2005) discussed the assumptions in the Milk per Acre index. Milk per Acre is a selection index used to measure which forage and hybrid gives the greatest return per acre. It has been used by the corn seed industry to help rank the broad range of hybrids available to the public. Allen identified two assumptions used in calculation of the index that dairy producers needed to be aware of. First, high-grain corn hybrids were better for silage than low-grain hybrids. Second, cropland base was the most important basis for the calculation of efficiency. Allen pointed out three parts of these assumptions that needed to be examined on an individual farm basis. First, the index assumed that corn silage costs less than corn grain and cropland was limited. Second, NDF would have been a better calculation for efficiency. Third, the number of cows supported by a given acreage was extremely variable, greatly diminishing the value of the index. He suggested constructing partial budgets for corn silage production and utilization, using actual on-farm prices of the ration components, then basing decisions off the individual operation’s budgets.

Barnett (2005) examined the economics of corn silage and alfalfa rotation for six different rotations using costs calculated from enterprise budgets and returns from historical average production in Wisconsin. He found a four year rotation (alfalfa establishment, alfalfa, alfalfa, and then corn) was the most profitable rotation under average production values and sensitivity analyses. It was also the most profitable rotation under the corn silage and alfalfa price differences examined.

Mullins, Grigsby, and Bradford (2009) looked at substituting distillers' grains for alfalfa, as well as when this trade-off should occur. Using break-even analysis, milk production was monitored to see if feeding alfalfa was justified. They concluded that milk production and body condition score were not affected with properly balanced rations. In addition, they suggested that when the milk-to-feed price ratio was low, adding alfalfa hay to the ration might not be profitable. However, they cautioned that availability of distillers' grains would affect the model outcomes.

Erdman, Piperova, and Kohn (2011) acknowledged corn silage had become the predominant forage source for dairy farms in the U.S. because of its high yield per unit of land area. They postulated that the dietary cation-anion difference (DCAD) inherent in alfalfa containing rations helped milk production. DCAD diets explain the interaction between positively charged calcium and potassium and the negatively charged chlorine (Stott R., Personal Communication 2011). Balancing these minerals in different ratios is advantageous at different times of lactation. Erdman, Piperova, and Kohn (2011) assumed that the DCAD ratios in alfalfa would increase production. They found this not to be true and could not prove an advantage in milk production when including alfalfa at the same rate as corn silage in the dairy ration.

Rankin (2014) addressed the topic of what forage dairy producers should select, i.e., alfalfa and/or corn silage, and in what ratio. The decision was broken into three components: agronomics, nutrition, and economics. For agronomics, he observed that "crop rotation is one of the most powerful agronomic tools producers have." When corn followed alfalfa, there was a 10% to 15% yield increase. Furthermore, higher production costs were incurred when corn followed corn. Risk was also greater when only one crop was planted instead of a rotation of the two. Nutritionally, it was pointed out that while both crops provided the needed fiber, corn silage was high in energy, while alfalfa was high in protein. Rankin observed the problem was becoming more muddled nutritionally because of the hybrid crops that were coming into the picture, but the optimal solution would fall between 25% and 75% corn silage as a percentage of forage DM in the ration. Economically, he identified four key factors to consider: DM yield per acre, stand life for alfalfa, acreage available, and machinery. Once costs were obtained, it was stressed that the comparison must be made on a "cow value" basis and that an individual farm's "cow value" most likely would be different than those found on neighboring farms.

Robinson (2014) assessed the strengths and weaknesses of alfalfa's nutritional value. The benefits that alfalfa brought to the ration included a high Total Digestible Nutrient (TDN) value, ideal fiber for stimulating increased buffering capacity and overall health of the rumen, high levels of crude protein, and an excellent source of minerals. The primary weaknesses of alfalfa were reflected in a lower energy value in comparison to other forages, especially corn silage, and a lower Neutral Detergent Fiber (NDF) value, which also implied lower DM intake. He suggested seed producers needed to focus on increasing fiber digestibility of alfalfa to improve overall animal performance. Robinson (1998), in a different publication, estimated the best way to determine Net Energy (NE) of alfalfa hay and corn silage using NDF and acid detergent fiber (ADF). He found that using NDF was more accurate in measuring the NE of both forages, but marginally less so for alfalfa hay than corn silage. He also suggested that testing laboratories should use NDF more so as to provide a better estimate of NE.

Literature Summary

While the research available on the alfalfa hay market is not very extensive, it does provide many important insights into its structure. It has been shown that ending stocks, precipitation, hay production, cattle inventory, livestock prices, alfalfa exports, and commodity prices all relate to alfalfa hay price changes. It has also been shown that structural changes have occurred in the past in the alfalfa hay market.

This research expands on the work done by the aforementioned experts by answering several questions. Has there been a structural change in the alfalfa market in more recent years? Are the aforementioned variables still relevant in a market that is experiencing new demand in the form of exports? How should the dairy industry react to these changes?

Alfalfa hay is a significant portion of the Western U.S. dairy cattle diet. The above literature shows that corn silage can replace some or all of the required forage but the question remains is it economically prudent to do so? Is the ratio of corn silage to alfalfa in the ration sensitive to different levels of milk production? If so what ratio is best for different levels of production?

Price changes in alfalfa hay directly affect the bottom line of the dairy industry. Producers should be asking what they need to do when alfalfa prices change. This research project will follow the outline Borton et al. (1997) applied in Michigan, but focus on an average sized Utah dairy to help answer these questions and identify additional areas where more research is needed.

CHAPTER 3

THEORY

Supply and Demand

The theory of supply and demand is the backbone of economics dating back to Adam Smith's idea of an invisible hand. Market demand is generally represented as a downward sloping line, referring to the relationship of when price decreases more quantity is demanded. This downward sloping line represents the utility that the consumers receives from consuming additional units of the product. Market supply is generally shown as an upward sloping line, reflecting the result of producing additional amounts of a product due to fixed factors of production. It illustrates the additional cost associated with every added unit of output, i.e., the portion of the marginal cost curve that lies above average variable cost. When supply and demand intersect, an equilibrium price occurs where the consumers' willingness to expend funds for the use of a product equals the price at which producers are willing to supply the product. Shifts in the amount supplied (or a change in quantity demanded), change prices by moving the intersection point. Supply and demand shifts are influenced by multiple factors, any of which can influence the equilibrium price.

Alfalfa hay price can be described as strictly the result of free interplay between supply and demand. The current year's supply of alfalfa is made up of current year production and carry over from the previous year. Production can be dissembled into acres planted and yield quantity and quality.

Demand is primarily a function of the price of competing crops for the land, livestock consumption (since alfalfa is almost exclusively consumed by animals), and the price that those animals of animal products bring. Livestock consumption can be distributed between exports (animals outside of the U.S. borders) and domestic consumption by dairy cows, beef cows and other livestock, such as horses or goats.

Competitive Market

The alfalfa hay market is made up of multiple small scale buyers and sellers, with no substantial barriers to entry or exit. While alfalfa hay has many grades of quality, quality doesn’t vary much when correct management practices for a specific region are followed. For example, if the region is prone to rain showers at the normal time of harvest, ensiling is a better management practice to produce high quality forage than dry bailing. The system of interactions between supply and demand found in the hay market are close to the competitive market model as described by Mankiw (2004). In his book, he put forward two characteristics of competitive markets: 1) the goods sold are all the same and 2) buyers and sellers are so numerous that no single buyer or seller has any influence over the market price (p. 66). Also, as Bazen et al. (2008) pointed out, buyers and sellers are at least aware of the current prices in their immediate area. Demand is such that while the individual firm’s demand curve is totally elastic, demand summed across the entire market becomes more inelastic meaning that while increased demand from one livestock producer will not have an impact on price, an increase in total demand will have an impact on price. For example, an increase in exports due to new and expanding export market could increase demand by significant amounts.

Similarly, while supply from an individual firm will not have an effect on overall price (because a firm's supply is considered inelastic in the short run and demand is considered elastic), supply becomes more elastic when individual supplies are summed across the entire market. If total market supply increases across the entire market and market demand is more inelastic, price will respond, though the exact nature of the resulting price change will depend on the relative elasticities of movements in demand and supply.

Derived Demand

Derived demand is an important subject when considering agricultural products. Derived demand is "processor demand for the input into a production process" (Hudson 2007). The derived demand for alfalfa is a function of the price of meat and milk, either at home or abroad. Alfalfa hay is demanded by the livestock industry to produce this meat and milk which, in turn, is demanded by the general public and as an input into other processed foods. The implications of derived demand on the alfalfa hay market are significant. As was explained in the supply and demand section above, alfalfa hay has largely only one use—livestock feed. As an example of the effect of derived demand, when milk price decreases, downward pressure is put on alfalfa price because dairy producers are not as willing to pay as much as before. This represents a classical example of derived demand affecting equilibrium price of alfalfa hay.

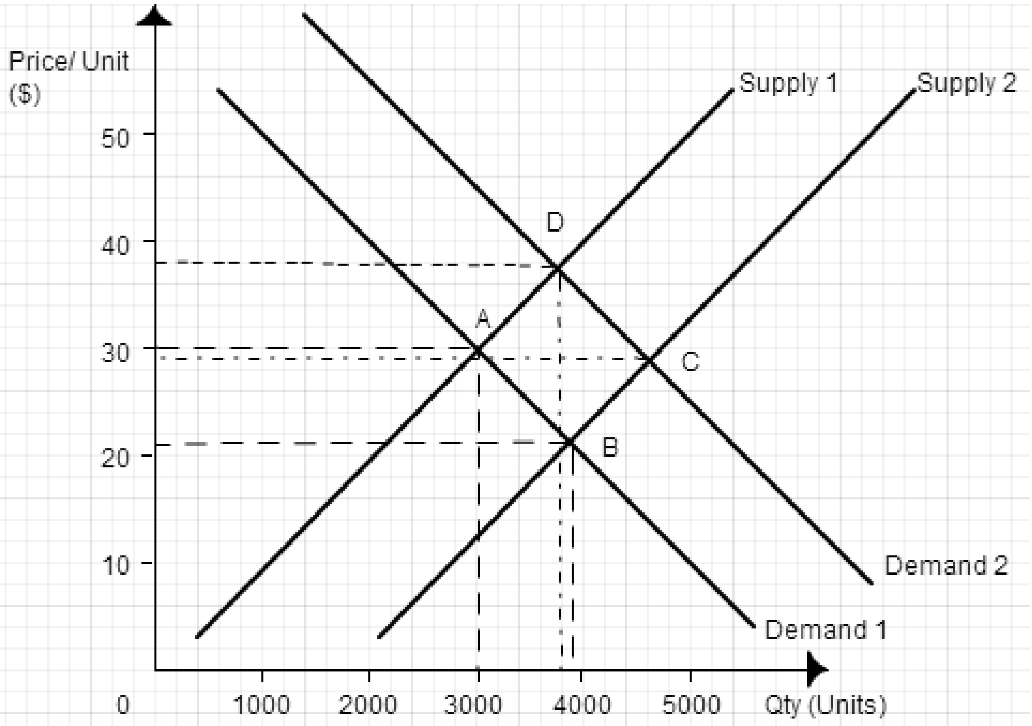
Simultaneous Changes

Simultaneous changes in supply and demand can make it difficult to assess what is happening in the market if only price data are available. As shown in figure 2 below, starting with demand 1 and supply 1, equilibrium price point A and it represents the prevailing market price. If supply is shifted to supply 2 and demand remains the same, point B is the new market price, but if demand shifts at the same time, point C becomes the market price. The last example of price moving from equilibrium A to C would represent a small decrease in price but large increase in the equilibrium quantity. So it really depends on the nature of the shifts in supply and demand as to the effect on the final equilibrium price. Interestingly, in multiple sectors of the economy, a price change is the only component of supply and demand interaction that is visible to the public, but behind the small price adjustments, supply and demand may have potentially undergone significant changes. To further show why movement in supply and demand is important to understand, consider point B (where supply 2 and demand 1 intersect) and assume this is the starting equilibrium supply and demand. If supply is decreased to supply 1 and demand increases to demand 2 the equilibrium moves to point A. The quantity supplied to the market will decrease marginally, if at all, but price would increase drastically. This would not be explainable if supply and demand were not measured and modeled simultaneously.

Structural Change

Structural change, often referred to as structural breaks in data sets, is described in *The New Palgrave: A Dictionary of Economics* (Eatwell, Milgate, and Newman 1987),

Figure 1 Simultaneous Changes in Supply and Demand



> "As a change in the relative weight of significant components of the aggregative indicator of the economy such as national product and expenditure, exports and imports, and population and the labour force.

Goddard et al. (1993) stated:

> In order to be structural change, the change in composition of the aggregate indicators for the organizations or institutions must be permanent and irreversible rather than a transitory or reversible change that may result from temporary scarcities or temporary exogenous shocks.

The Chow test is a common test for structural change. Chow's thesis (1957) looked at automobile purchases previous to 1954 and compared them to automobile purchases from

1954 to 1957. In a latter publication, Chow (1960) explained that when linear regression is used to represent economic relationships, occasionally the question can be asked if the significant components remain static (such as automobile purchases in 1954). The question is whether the coefficients are statistically equal if the regression is broken into two sub-set regressions. The Chow test is used to answer this query. Possible changes that the alfalfa hay market have experienced could be new demand in the form of expanding exports, a change in the magnitude of the derived demand from U.S. beef/dairy producers, or it could even be due to the underlying change in the cost structure of producing alfalfa. None of these are easily explained.

Risk

Definitions of certainty, uncertainty, and risk may help in better understanding this subject. Fleisher (1990) gives a relativity succinct definition of risk:

> When a decision is made under certainty, each possible action has only one possible consequence. This one-to-one correspondence between the action and its consequences occurs because the decision-maker knows both the event that will occur and its effect of the action selected. In contrast, a decision made under uncertainty has at least one action choice with more than one possible consequence. Many different events may occur between the time the decision is made and the time the consequences are felt (pp.13-15).

When decisions are made under “certainty” only one result is possible, as noted above. Uncertainty exists when multiple results are possible and the results are unquantifiable.

Risk occurs when multiple results are possible and probabilities associated with each multiple result can be quantified.

Risk takers can be categorized three ways: risk averse, risk neutral and risk seeking. Risk adverse people would prefer, if possible to have the least risk possible, while risk neutral people are unaffected by the risk that they take. Risk seeking people actually prefer more risky outcomes. It is generally assumed that producers are risk averse (Hudson 2007).

There are five general types of risk: production (yield), price (market), institutional (government), human (personal), and financial. Alfalfa producers are exposed to all these forms of risk, but two are most important, namely yield and price. There are ways for producers to mitigate these risk through crop diversification, crop hedging (or in the case of alfalfa, cross hedging), and, as Hudson (2007) discusses, vertical integration. Technology also can help manage risk through better management practices. Diversification of crop production is comparable to portfolio theory that states once the level of risk aversion is identified, a range of investments can be found to maximize return and protect against unforeseen events (Markowitz 1952). The same concept can apply to crop production given the environment of the area some crops have higher risk associated with production than others.

Hedging using commodity markets represents an opportunity for producers to shift price risk to the market place. While a profitable price is not always present in the market place, it remains a tool to mitigate risk. Unfortunately, hedging is not an option because there is no futures market for alfalfa hay, but cross hedging can be done. Cross hedging is done by identifying similar trends in a second commodity and buying futures in that commodity to offset the associated price risk of the first. For example, buying corn futures to hedge alfalfa price.

Hudson (2007) stated that “the theory of risk suggests that increases in risk should lead to a greater use of contracting/vertical integration on the part of the producer” (p. 182). This is seen in the data accumulated by the difference between the cash sales and total alfalfa production. In many cases the alfalfa producer has vertically integrated into livestock or the livestock producer has grown the required alfalfa. The vertical integration of alfalfa production and livestock operations in many instances is done to hedge against supply and demand risk.

One of the goals of this thesis is to test for structural change and quantify the factors that are influencing the alfalfa hay market. Possible changes to the derived demand influence in the milk-to-alfalfa price relationship has increased the uncertainty of alfalfa producers and buyers. By identifying if a structural change has taken place, and assigning coefficients to the relevant variables that influence alfalfa price, some of the risk associated with the uncertainty column will be able to be moved to the risk column because it can be measured and better acted upon.

CHAPTER 4

METHODOLOGY AND DATA FOR THE ECONOMETRIC MODEL

This chapter is divided into two sections. The first section discusses the methods used to accomplish the objectives relating to the alfalfa hay market which are to identity structural change in the alfalfa hay market and find which components of demand are influencing the change in alfalfa price and in what magnitude. The second section covers the data that were acquired and the way they were handled in the regression analysis.

Structural Change of the Western U.S. Alfalfa Hay Market:

Ordinary least squares (OLS) was used to generate the regression analysis once the data were formatted. OLS is a regression estimation technique that calculates the coefficients of an equation such that the vertical sum of the squared residuals are minimized (Studenmund 2011), which means that OLS estimates a line through the data set that minimizes the vertical sum of the errors from the line to each of the data points.

OLS operates under 7 classical assumptions: 1) the model is linear, is correctly specified and has an error term, 2) the error term or residual has a mean of zero, 3) all independent variables are uncorrelated with the error term, 4) the error term is not correlated with itself from one observation to the next, 5) the error term has a constant variance, 6) no independent variable is a perfect linear function of any other independent variable, and 7) the error terms have a normal distribution (optional except for hypothesis testing).

Violation of the first classical assumption occurs when an important independent variable is omitted or when incorrect functional form is used. The error term is included to account for minor omitted variables and randomness, but not important components of the dependent variable. Since economics is the study of production, consumption and the transfer of goods and services between humans and because humans are not always predictable, the error term helps to capture this randomness.

Classical assumption 2 states the mean value of the error is zero. Essentially, the constant accounts for the portion of the dependent variable that is unaccounted for by the independent variables and the error term accounts for randomness.

Classical assumption 3 specifies the error term is unrelated to any independent variable. It is most often violated when an important variable is omitted from the estimation but it is correlated to at least one of the independent variables, leading to the error term being correlated to the independent variable. OLS then assigns the portion of the effects that are correlated to an included independent variable and the rest to the error term. This results in the error term capturing the effects of the omitted variable and being related to at least one independent variable.

Classical assumption 4 states the error terms are not related to each other, i.e., the first error term being positive has no effect on the second error term being positive. Economic models that follow individuals or firms through time (or time-series data sets) most often violate this assumption, which is known as serial correlation.

Classical assumption 5 states the error term has a constant variance. This means that on average the distance from the mean error term does not increase or decrease over the data set. When the opposite happens, the problem is identified as heteroskedasticity. This is most often a problem with cross-section data.

Assumption 6 states that there is no perfect correlation between independent variables. This is required because if the movement of one variable is mirrored by at least one other variable, then OLS cannot distinguish between the two. This is referred to as multicollinearity. Multicollinearity is a matter of degree, not existence.

Assumptions 2, 4, and 5 define requirements for the error term, but thus far nothing has been said about the shape of the error term distribution. Assumption 7 states that the errors should have a normal distribution, which means that both sides of the distribution are approximately symmetrical and the distribution is fully defined by its mean and standard deviation. This condition is much more likely to occur with large data sets.

Five basic problems occur that violate the classical assumptions, including an unnecessary variable in the estimation, excluding a necessary variable from the estimation, serial correlation, heteroskedasticity, and multicollinearity. Identifying and solving these problems, where possible, is important in effective model estimation.

The inclusion of an irrelevant variable in a regression equation typically does not have an impact on the other variables' coefficients. It can reduce the adjusted R^2. This is often a problem when the theory associated with the model is not thoroughly vetted. This included irrelevant variable will typically have an insignificant coefficient.

When important variables are omitted, not only is relevant information missing in the results, but the estimated coefficients are biased. One sign of an omitted variable is unexpected signs on the estimated coefficients. The best way to ensure that all relevant variables are included in the regression is to examine the theory behind the estimation and do a thorough examination of the previous literature on the subject.

Serial correlation of the error term most frequently occurs in time-series modeling where there is a trend or cycle evident in the error term. This trend or cyclical pattern can often be isolated. While serial correlation doesn't cause bias in the coefficient estimates, it does affect the standard errors, making hypothesis testing unreliable. Two types of serial correlation are observable, pure and impure. Impure serial correlation is the result of an omitted variable or incorrect specification form. Pure serial correlation occurs in a correctly specified equations with no missing variables and will, hereafter, be referred to as serial correlation. The Durbin-Watson d-statistic can be used to find serial correlation, but this approach may be unreliable due to the nature of the test. The roe (p) test can be used as a way of identifying serial correlation. In most cases where serial correlation is found, generalized least squares (GLS) can be used to estimate the coefficients utilizing an AR(1) term, which assumes a first-order correlation between near-terms. Newey-West corrected standard errors can also be estimated to avoid the problems associated with first-order serial correlation. However, using an AR(1) term has the disadvantage of making many of the other variable coefficients' insignificant. In panel data this is a more serious problem because some of the usual adjustments to the standard errors that can be made when regressing using regular data will no longer work for balanced panel data.

Heteroskedasticity occurs when the errors do not have a constant variance over the entire range of observations. It is normally a problem in cross-sectional data sets, though it can occur with other data types as well, and causes bias in the estimated standard errors producing unreliable hypothesis testing conditions. It can be defined as pure and impure like serial correlation. Impure heteroskedasticity is the result of an omitted variable or an error in specification. Pure heteroskedasticity is a function of the error term in a correctly specified regression. The Park test can be used to identify heteroskedasticity by using the residuals as the dependent variable of a new regression with the independent variables being used to estimate the amount that the errors vary. Newey-West corrected standard errors can be used to correct for heteroskedasticity, as well as for serial correlation.

Severe multicollinearity is a perfect or near perfect linear relationship between the values of two or more independent variables. Multicollinearity actually causes bias in the t-scores of the estimated coefficients. It may exist in any data set and likely exists in all data sets to some degree. The question with multicollinearity becomes, “How significant is it?” One clue that can show possible multicollinearity occurs when variable-to-variable correlation coefficients are very high. The severity of these highly correlated independent variables can then be examined using variance inflation factors (VIF) to determine if multicollinearity is serious enough to warrant action. If it is deemed to be severe, three things can be done: nothing, drop or combine the correlated variables, or increase the sample size.

When time-series and cross-sectional data sets are combined, the resulting data set is known as a panel data set. When each variable has observations for every year it is referred to as a balanced panel data set. The data used in this analysis are considered part of a balanced panel data set because they covers 13 states over 32 years. By combining time-series and cross-sectional data, the problems associated with each type are present in panel data sets. The software package Eviews was used to analyze this balanced panel data set. In total, 429 observations were used in the estimation of the econometric equations.

To estimate the market price of alfalfa hay the important components that influence price needed to be identified. As was outlined in the theory chapter, alfalfa is primarily used as a forage in milk and beef production. Thus, it was obvious that milk and feeder calf prices would be necessary. Both of these variable were lagged because of the nature of the recorded values. Milk and feeder price are on a January to December time frame whereas alfalfa hay is on a June to May time frame. Price was not the only component of the livestock industry that was deemed necessary. Animal inventory was also included to account for changes in total demand. Exports were included because of their increasing importance. Ending alfalfa stocks, alfalfa production, alfalfa quality, competing commodity price and a proxy for costs have all been included in past research and were included in the model. A dummy variable representing potential structural change was also included in the model. The estimated equation was:

$$\begin{gathered}\mathit{Market\ Price}_{st} = C + \mathit{Milk\ Price}_{st} + \mathit{Milk\ Price(-1)}_{st} + \mathit{Feeder\ Price}_{st} + \mathit{Feeder} \\ \mathit{Price(-1)}_{st} + \mathit{Exports}_{st} + \mathit{BeefI}_{st} + \mathit{DairyI}_{st} + \mathit{HStocks}_{st} + \mathit{Alfalfa}_{st} + \mathit{Quality}_{st} + \\ \mathit{Commodity\ Price}_{st} + \mathit{Costs}_{st} + \mathit{Structural\ Dummy}_{st} + e_{st}\end{gathered} \tag{1}$$

where Market Price was the price of alfalfa hay, Milk Price was the average price received by producer in each state and the Milk Price(-1) was lagged one year. Feeder price was the USDA calf price and it was also lagged one year, Feeder Price(-1), Exports represented the alfalfa exports allocated to each state, BeefI and DairyI were the inventory of beef and dairy animals, respectively, for each state and year, the Stocks variable was the ending stock of alfalfa hay in each state, Alfalfa was the amount of alfalfa produced in each state, Quality was modeled by a proxy precipitation variable, Commodity Price was a weighted average price of corn, wheat, and barley, Costs were represented by a fuel price index, and the Structural Dummy was used to capture the suspected structural change in the market. It was hypothesized that both milk price variables, both feeder price variables, and the exports, beef inventory, dairy inventory, commodity price and cost variables would all have positive coefficients. Alfalfa hay stocks, quality and alfalfa production were hypothesized to have negative coefficients.

Data for the Econometric Model

Data were compiled on commodity prices, feeder steer prices, milk prices, costs, precipitation, exports, ending stocks of alfalfa, and dairy and beef inventory numbers. The United States Department of Agriculture's (USDA's) Quickstats database supplied the majority of the data used. The data set was also supplemented using data from the Livestock Marketing Information Center (LMIC), Bureau of Labor Statistics (BLS), the Foreign Agricultural Service (FAS), and the National Climatic Data Center (NOAA).

The data used to measure components contributing to alfalfa price and structural change in the alfalfa hay market covered ten Western U.S. states, i.e., Oregon, Washington, California, Idaho, Utah, Nevada, Arizona, New Mexico, Colorado, Wyoming, and four Midwestern states, i.e., Minnesota, Indiana, Wisconsin, and Michigan. The data years ranged from 1980 to 2012, inclusive. Montana was excluded from the data set because it had little alfalfa production relative to other states in the West and was primarily comprised of cow-calf operations, with very few dairy operations. The northernmost Midwest states were selected because of the relatively large dairy industry found there.

Once the needed variables were identified and the initial data gathered from the various sources, two problems became apparent. First, the data for Nevada had numerous missing observations for almost all variables, with some of the data gaps actually larger than the existing data. Second, feeder steer prices from USDA-NASS Quickstats (2014) also had large time intervals where no data were available.

To fix the first problem, Utah and Nevada data were combined using production-weighted averages. Production data, such as for barley, wheat, alfalfa, and milk, were summed first. May ending stocks of alfalfa hay and beef and dairy inventories were also summed for the two states creating total production values for each variable. The proportion from each state relative to the total of the two states for each commodity was used as the weight to determine the combined commodity prices. Precipitation was averaged for the two states and costs were represented by the fuel prices paid index, which was the same for every state, so no further adjustments were needed for the variable selected to represent costs.

The fuel prices paid index was used as a proxy variable to represent the changing cost of alfalfa production. It was determined that a fuel cost index would adequately reflect the movement of costs associated with planting, fertilizing, and harvesting alfalfa. A Canadian market outlook report stated that in 2010 fuel and fertilizer represented 16%

of farm expenses (AGR 2012). We assumed a fuel cost index would reflect the changes in production costs better than a general cost index since so many of the farming operations are tied to fuel and fertilizer. The producer price index for fuel was obtained from the Bureau of Labor Statistics (BLS.gov 2013).

The second problem of missing feeder prices was solved using two approaches. First, we identified which size of beef animal the USDA-NASS Quickstats was tracking and filled in as much missing data as possible with data from the LMIC. Unfortunately, LMIC data only went back to 1990. For data gaps earlier than 1990, we used auction reports compiled by LMIC (2014) and identified which animal weight price most closely matched the USDA data. Regrettably, this method did not allow us to complete the feeder price data set since not all states had auctions that were reported in the LMIC spreadsheets. The second method used to fill in missing data was to average the price for each year across all states. The percentage differences between each state and the overall yearly price was then determined. This yearly percentage was averaged for feeder prices in each state over the entire data base finding an overall differential percentage on a state-by-state basis that might be expected over the open or missing data points. This average percentage difference in price was then used to fill the data gaps. This second method was also used to fill in the few missing alfalfa hay price data observations as well.

Allocating hay exports was the next challenge. Hay export data were found in the USDA-FAS (2013) data base. This source provided total U.S. alfalfa exports in dollars. However, all other data were on a state-by-state basis, requiring that we allocate exports to individual states. In two reports, one from the FAS (Tyng 2013) and the other from the

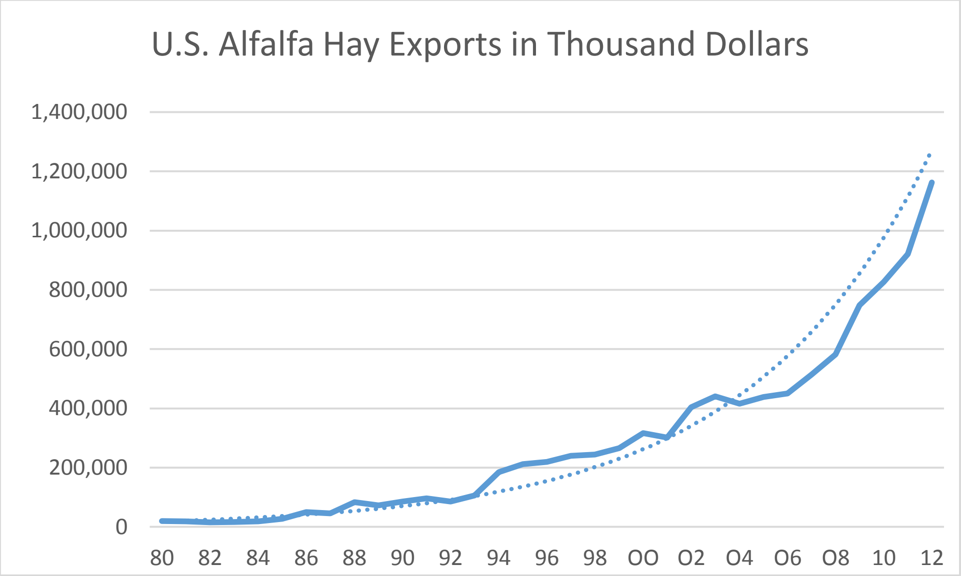
National Alfalfa and Forage Alliance (Putnam et al. 2012), it was noted that 99% of alfalfa exports originated from Arizona, California, Idaho, Nevada, Oregon, Utah, and Washington. It was assumed in this thesis that the Pacific Northwest would account for 40% of exports and the Southwest would account for 60% of exports. Within each region, exports were allocated using a weighted average based on cash sales of alfalfa hay (Jerardo 2014). Cash Sales were obtained from the USDA's Economic Research Service (ERS) farm income and wealth statistics (ERS 2013).

Even though it may be argued that exports come primarily from California, Washington and Oregon, it is recognized that some exports occur from each of the other states. Furthermore, it is reasonable to assume that alfalfa hay exported out of California, Oregon and Washington has to be replaced by hay from Utah, Nevada, Idaho, etc. Hence, though it is impossible to measure the international exports from each state, a regional allocation intuitively makes sense.

A dummy variable was included to account for the structural change exports might have experienced. As illustrated in figure 1, exports have been slowly trending upward from 1980, but began to increase at a faster rate beginning in 1994 than before. Figure 1 is the graph of the data that was used as the basis to estimate when the dummy variable would switch from zero to one.

Corn, barley, and wheat, were incorporated into the model based on two criteria: First, they were used by multiple authors in the literature to help forecast alfalfa hay price (Brazen, Roberts, Travis, and Larson 2008, Konyar and Knapp 1988, Blake and Catlet 1984, Mayer and Yanagida 1984, Blake and Clevenger 1984). Second, Lubowski, Plantinga, and Stavins (2008) found that land use changes had been steered by anticipated economic returns on investment. With the price of these other commodities having changed in a relative sense, it was expected that they would impact hay acreage and, consequently, price.

Figure 2 Alfalfa Hay Exports in Thousand Dollars



Note: Graph of alfalfa hay exports in thousand dollars from FAS

Commodity prices have risen in the past decade, offering a viable alternative to alfalfa production. Consequently, they represent higher potential returns to growers. Assuming that corn, wheat, and barley are substitutes for alfalfa hay both in the ration and in crop acreage, a change in their prices could increase alfalfa demand and, thus, alfalfa price. Corn, barley, and wheat price were combined into a weighted value of competing crops using the same process as was followed with the Utah and Nevada data, comparing state total production to overall total production.

Precipitation data were taken from NOAA (2014) and used as a proxy for alfalfa hay quality. These data were constrained to five calendar months, including May through September, as these months typify the average growing season of alfalfa for most states in the data set. Precipitation was averaged from 1901-2000 for each state and subsequently used as the normal year base value. The amount of precipitation over or under this base was used as the quality proxy variable. For example, average precipitation from May to September in Utah over the 100 years of observations was 4.59 inches. In 2012, Utah received 3.42 inches of precipitation for the months May to September, resulting in a -1.15 difference relative to the 100 year average. This value was used to measure alfalfa quality in 2012 for Utah. As used in this analysis, a negative value would be associated with higher quality hay. Similar calculations were made for every state and year in the sample.

Crop production, ending stocks, milk price, and livestock inventory data were collected from USDA-NASS Quickstats (2013) database. The mean and standard deviation of each variable are provided in table 1. The standard deviation associated with each variable provides some indication of the risk associated with each variable. Those variables with higher standard deviations are also those variables with the highest risk. Precipitation had the largest variation in the data set, other than the structural dummy, with a standard deviation of 30% from the mean. Exports and dairy inventory had 11% and 6% deviations, respectively, while ending stocks had just a 5% deviation. The complete summary statistics for each variable can be found in Appendix A.

Table 1 Mean and Standard Deviation of Variables

	Mean	Standard Deviation	% Variation
Alfalfa Price ($/ton)	99.97	1.89	2%
Beef Inventory (10,000 hd)	47.983	1.116	2%
Commodity Price ($/bushel)	2.786	0.025	1%
Costs (Index = 100)	117.533	4.028	3%
Dairy Inventory (10,000 hd)	39.83	2.36	6%
Ending Stocks (10,000,000 tons)	50.153	2.333	5%
Exports (10,000,000 tons)	2.245	0.241	11%
Feeder price ($/cwt)	92.38	1.39	2%
Hay Production (10,000,000 tons)	323.98	9.57	3%
Milk Price ($/cwt)	13.950	0.108	1%
Precipitation (3 Digit Index)	0.345	0.102	30%

Note: Selected Descriptive Statistics of the Variables, Dairy and Beef Inventories are in 10,000 cow units, Ending Stocks and Hay Production are in 10,000 ton units, Exports are in $10 million units

CHAPTER 5

METHODOLOGY AND DATA FOR THE SIMULATION MODEL

This chapter is divided into two sections. The first discusses the methodology of the IFSM to model an average Utah dairy operation to accomplish the remaining objectives of: 1) simulating the financial performance of a Utah dairy using three ratios of alfalfa and corn silage to satisfy the forage requirement, and 2) analyzing these rations at three levels of production. The second section covers the data used for this model and the assumptions made with respect to the data.

IFSM for an Average Utah Dairy

Livestock production is a complex process with multiple components that affect the eventual profit of the operation. IFSM is unlike most farm models because it simulates all major aspects of the operation at a process level. It originated in the 1980’s when the effort was made to construct a model to link alfalfa and corn production with dairy intake models. Today, IFSM uses water and nitrogen availability, ambient temperature and solar radiation to simulate the daily growth and development of alfalfa and corn. This is simulated over 25 years to give average forage yield and quality outputs to provide some measure of the variation or risk associated with these variables. IFSM couples this with a cost-minimizing linear program for the dairy diets which are constrained to utilize home grown feed first, then purchased the balance needed, resulting in a tool for researchers to simulate the effect of management or equipment changes to the net return of the whole operation. All process level performances were simulated to determine production costs, income, and economic return for each year simulated.

In this section, the assumptions integral to IFSM will be discussed. The major components of a dairy operation were assumed to include: crop and soil characteristics, machinery, tillage and planting, crop harvest, crop storage, lactating herd and feeding, nutrient management, and various economic measures. Each one of these items was simulated using the Salt Lake City weather file option and the input options available to the researcher. The weather file took into account total daily solar radiation, mean temperature, maximum temperature, minimum temperature, total precipitation, and average wind speed, with weather being one of the major risk factors for production agriculture.

Key assumptions associated with the crop and soil component were that alfalfa is a monoculture crop, grown on well drained soils, with no significant fertility problems. Corn growth was estimated for a single plant, then multiplied to account for the whole crop. Crop rotation was also taken into account in adjusting corn yield according to what the preceding crop was. If corn followed corn, there was a 10% reduction in yield.

Performance and resource utilization rates included: throughput capacity, engine load, fuel consumption, electrical use, and labor requirement. Field operations were only allowed when conditions were suitable for the task being performed. This was determined using the available weather data. It was assumed that one person was required for each operating piece of equipment and that person had to be working every hour the piece of equipment was in operation. Allowable days of operation for planting and harvesting were estimated using daily simulated soil moisture conditions throughout the top three levels of soil.

Corn silage harvest was only simulated if a designated storage facility was available. Once the designated facility was full, the remainder of the crop was harvested for high moisture corn until the high moisture corn facility was full. Once this occurs, the remainder of the corn is harvested as dry corn. If custom operators were used to harvest the crop, all machinery and labor costs are calculated as part of the custom rate. Once all crops were put into storage, storage loss was accounted for depending on what harvesting process and type of storage were used.

The dairy herd was divided into six distinct groups: young stock under one year of age, young stock over one year of age, three groups of lactating cows, and non-lactating cows. The preferred forage for lactating cows was assumed to be corn silage, high-quality alfalfa silage, and high-quality baled alfalfa hay. Cost minimizing linear programming was used to formulate the ration for the dairy herd. It was constrained by five equations representing: physical rumen fill, effective fiber, energy requirement, rumen degradable protein, and rumen un-degradable protein.

The cost of facilities and equipment, minus its salvage value, were depreciated over its useful life. Maintenance costs were also accounted for by a fixed percentage rate suggested by the user. For example, machinery was estimated to have an economic life of 10 years with a 30% salvage value and a 2% of original value maintenance cost per year. Cost of cropping included the cost of fertilizer, seeds, chemicals, and additional processing of feed such as drying of grain. Prices of each component were set by the user.

Farm revenue was determined from three areas of the farm: milk revenue, animals sold, and extra crop sales. All prices entered were five-year averages where the information was available and expert estimates of long term prices where data were not available as outlined in the data section.

To determine the required acreage for each simulation assuming a 400 cow dairy, the required feed was originally estimated using the following assumptions. The average body weight of mature animals was 1500 lbs. DM intake was 55% forage, consisting of various alfalfa hay and corn silage mixtures for mature animals. Alfalfa was assumed to be 90% DM and corn silage 35% DM. Alfalfa hay production was estimated as 7 tons per acre and corn silage production at 30 tons per acre.

Production of the lactating herd was simulated at three levels, and three different ratios of alfalfa and corn silage, each requiring different amounts of forage intake (Table 2). At 18,300 lbs., DM intake was 47.8 lbs. per day; at 22,500 lbs. DM intake was estimated to be 51.9 lbs. per day; and at 26,700 lbs. production, 56.1 lbs. of DM were estimated to be needed daily as recorded in. These daily requirements were then expanded to calculate the required yearly tonnage for the lactating herd, table 3. High moisture corn was kept constant across all levels of production and ration mixes.

Calf mortality rates were estimated to be: 14% from birth to 7 months of age, 2% from 7 to 12 months beyond the 14% from birth to 7 months, with a additional loss of3.5% from 12 to 24 months beyond the cumulative mortality that 12 months. All bull calves were asssumed to be sold in the first week of life. Assuming a 12 month caving interval, 170 heifers were under one year of age and 164 over one year.

Table 2 Daily Lactating Cow Feed Requirements for Select Levels of Milk Production

	18,300 lbs. Production			22,500 lbs. Production			26,700 lbs. Production		
	25%	50%	75%	25%	50%	75%	25%	50%	75%
Dry Matter (lbs.)	47.8	47.8	47.8	51.9	51.9	51.9	56.1	56.1	56.1
Alfalfa Hay	7.2	14.5	21.7	7.8	15.7	23.5	8.5	17.0	25.5
Corn Silage	56.3	37.6	18.8	61.2	40.8	20.4	66.1	44.1	22
High Moisture Corn	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0

Notes: Forages are at 90% DM for Alfalfa and 35% DM for Corn Silage, %'s represent how much alfalfa is in the ration.

Table 3 Dairy Herd Requirements Tons per Year for Select Levels of Milk Production

	18,300 lbs. Production			22,500 lbs. Production			26,700 lbs. Production		
	25%	50%	75%	25%	50%	75%	25%	50%	75%
Alfalfa Hay	527	1055	1583	1141	1714	2287	1188	1807	2427
Corn Silage	2375	1583	791	3144	2284	1425	3352	2423	1494
High Moisture Corn	876	876	876	876	876	876	876	876	876

Notes: Forages are at 90% DM for Alfalfa and 35% DM for Corn Silage, %'s represent how much alfalfa is in the ration.

The required forage for the replacement herd was estimated at a daily rate so calves from 7-12 months of age would consume 7 lbs. of alfalfa and 6 lbs. of corn silage, those 12-19 months of age were assumed to consume 11.2 lbs. of alfalfa and 8.8 lbs. of corn silage, while those 19-24 months of age would consume 16.1 lbs. of alfalfa and 7.9 lbs. corn silage, as given in table 4, all on a DM basis. This was also expanded to estimate total yearly requirements, table 5.

Table 4 Replacement Heifers Daily Feed Requirement

Age in Months	7-12	12-19	19-24
Daily Dry Matter (lbs.)	13.0	20.1	24.0
Alfalfa Hay	7.7	12.3	17.7
Corn Silage	9.9	14.5	13.0

Notes: Forages were assumed at 90% DM for Alfalfa and 35% DM for Corn Silage

Table 5 Replacement Herd Yearly Requirements

Forage	DM
Alfalfa Hay Tons	631.9
Corn Silage Tons	1,615.4

Notes: Forages were assumed at 90% DM for Alfalfa and 35% DM for Corn Silage

Once the estimated tonnage was known, required acreage was calculated by assuming the above yields and forage DM. The range of required acreage was from 129.2 acres of corn silage in the lowest producing herd to 319.3 acres in the high producing herd. Alfalfa acres ranged from 174 in the low producing herd to 385.2 in the high production herd. Total required acreage for the various forms simulated went from 628.5 to 702 acres. Required acreage is included in table 6.

Table 6 Required Forage Acreage for Select Levels of Milk Production

	18,300 lbs. Production			22,500 lbs. Production			26,700 lbs. Production		
	25%	50%	75%	25%	50%	75%	25%	50%	75%
Alfalfa Hay	174	257	341	181	272	363	188	286	385
Corn Silage	280	204	129	299	217	135	319	230	142
High Moisture Grain Corn	174	174	174	174	174	174	174	174	174
Total	628	636	645	655	664	673	682	692	702

Notes: Forages were assumed at 90% DM for Alfalfa and 35% DM for Corn Silage

Table 7 outlines the prices and percentages used in the simulation. Prices represent long term values based on the last five year averages. Where it was not possible to find five years of data USU extension experts were consulted to provide the needed information.

Table 7 Economic Parameters and Prices Assumed in the Forage Analysis

Parameter	Value
Milk Price, $/cwt	16.88
Labor, $/hour	10
Diesel Fuel Price, $/gallon	2.54
Electricity Price, $/kWh	0.0851
Seed and pesticide cost	
Alfalfa Establishment, $/acre	79
Established Alfalfa Stand, $/acre	15
All Corn, $/acre	120
Corn Following Corn, $/acre	5
Fertilizer Costs	
Nitrogen, $/pound	0.4
Phosphate, $/pound	0.48
Custom Machinery Costs	
Grain Corn Harvesting, $/acre	43.5
Selling Price Feed	
Alfalfa Hay, $/acre	160
Corn Silage, $/acre	90.75
High Moisture Grain Corn, $/acre	225
Buying Price of Feed and Bedding	
Steam Flaked Corn, $/ton	325
Canola Meal, $/ton	427
Alfalfa Hay, $/ton	160
Sand, $/ton	10
Economic Life and Salvage Value	
Life of Machinery, yr.	10
Salvage Value of Machinery, %	30
Life of Structures, yr.	30
Salvage Value of Structures, %	10
Interest Rate %	5.26
Property Tax %	2.5

These numbers were used in the simulation to assess which ration was the most economical for the operation. In each simulation for each level of production: acreage was changed to reflect the forage requirement, corn silage storage was sized according to estimated needs, and it was designated how much alfalfa hay was to be incorporated into the ration.

Data for the Dairy Simulation Model

Using the Integrated Farm System Model (IFSM), three combinations of forage inputs were simulated for three levels of milk production. Data for the dairy simulation model were broken into four areas: dairy production, agronomic production, equipment and economics. Subject matter experts from Utah State University (USU) were consulted and recommendations from publications were used where available and applicable. The operation modeled was a 400 cow dairy centered in Box Elder County, Utah. IFSM included a weather file for Salt Lake City, Utah, which was used in the simulation model.

Dr. Allen Young (Personal Communication 2014), USU Extension Dairy Specialist, provided information on the dairy herd requirements, using Utah Dairy Herd Information Association (DHIA) records as the basis for herd size, production levels, and replacement death loss (DHIA 2013). It was assumed that the ration consisted of 55% forage and 45% concentrates on a DM basis for the lactating animals. Dr. Young calculated three levels of forage DM intake based on Utah DHIA average animal size and three levels of milk production.

The forages used were alfalfa hay and corn silage. Alfalfa and corn silage were fed in ratios of 25:75, 50:50 and 75:25 percent on a DM basis, respectively, to animals producing 18,300, 22,500 and 26,600 pounds of milk a year, respectively. The calculated DM intake was used to determine total forage requirements. Twelve pounds of high moisture corn was included in the ration for all levels of production with grain being set as the energy supplement if an insufficient amount was supplied in the diet. Canola meal was selected as the crude protein supplement source. Replacement death loss was assumed to be 14% for up to six months, then another 2% for the animals remaining after the 14% loss from six months to one year of age. Finally, an additional 3.5% was estimated to be lost for the remaining animals from one to two years of age.

Dr. Earl Creech (Personal Communication 2013), USU Extension Agronomist supplied typical irrigated crop yields, nutrient requirements, alfalfa stand life, and corn plant populations for Box Elder County. These estimates, along with the calculated forage requirements, were used to estimate how many irrigable acres were needed. It was assumed that acreage would not be a limiting factor, so the highest forage requirements from the dairy operation was used to estimate desired acreage. It was also assumed that management was sufficiently proficient in crop production so as not to have a negative impact on production at any level of the operation. Crop planting dates and average harvest dates were also recommended by Dr. Creech, with acknowledgment that these dates were dependent on weather-related events that the simulation would account for. Dr. Neil Allen (Personal Communication 2013), Extension Irrigation Specialist, augmented the agronomy estimates utilizing Crop and Wetland Consumptive Use and Open Water Surface Evaporation for Utah (Hill, Baker and Lewis 2011), from which maximum irrigation requirements for each crop were established.

The equipment used in the simulation was conditional on the number of acres to be tilled and harvested, as well as the size of the dairy operation. Patterson and Painter (2011) published custom rates for Idaho agricultural operations which were used in the simulation for those operations hired out within the IFSM model. IFSM allows the researcher to select which, if any or all, equipment operations can be performed by custom operators. Harvest of corn grain was assumed to be the only custom operation used in the model. In addition to the custom rates utilized, Patterson and Painter included formulas for calculating acres per hour and horse power required for each operation, which were then used to determine optimal equipment needs. As an example, at 26,700 lbs. of production and fed 75% corn silage, it was estimated the lactating herd would require 320 acres of corn silage to be planted for the lactating herd and its replacements. Since this was the most corn silage harvested, equipment was sized for this scenario. For example, using the formulas found on page 5 of Patterson and Painter's report and the table on page 7 (2011) it was estimated that a large tractor-pulled forage harvester could harvest 2 acres an hour for 10 hours a day, or 20 acres a day, taking 16 days to harvest the assumed acreage if no breakdowns occurred. A self-propelled forage harvester could accomplish the same task in 5 days if no breakdowns occurred. However, it was assumed that the 16 days a tractor-pulled harvester would take to complete the task were within reason, so the tractor-pulled equipment match was used.

The economic values used in the simulation model came from a variety of sources, some of which were used in the alfalfa hay market analysis above. Idaho State University (CALS 2014) has posted online a dairy budget from which most animal expenses originated. Any additional information that was needed and not found in this budget was provided by Dr. Young (Personal Communication 2013). Feed and fertilizer prices were obtained from the USDA-NASS Quickstats (2014). Western Ag. Credit

(Personal Communication 2013) provided long and medium term interest rates. Electricity and fuel prices were available on the Energy Information Administration website (2014). Feed, fuel, crop, electricity, interest, wage and fertilizer prices were based on five year averages in an attempt to reflect longer term prices. It was assumed that the current realities of the overall market were not going to change in the near or intermediate future and, thus, the last five years should represent longer term market conditions. However, it should be noted in the case of increasing costs, a five year average will typically understate the current costs. Enterprise budgets from USU's Applied Economics Department for Box Elder County were used in the analysis (Holmgren, Curtis, and Snyder 2011).

The data presented above were used to simulate an average Utah dairy operation in order to assess what forage should be fed to the various farm operation's animals to generate the largest economic benefit. The following chapters will review the results of the two models outlined in the previous chapters and finally the implications and conclusions of the thesis.

CHAPTER 6

RESULTS AND DICUSSION

This chapter is divided into two main sections. The first section discusses the regression results and tests performed to identify the components of the Western alfalfa market and assess if structural change had occurred in the Western U.S. alfalfa hay market. The second section discusses the results of the integrated farm system model (IFSM) used in simulating an average Utah dairy. The objectives of this second section were to: to assess, through simulation, the financial performance of a Utah dairy using three ratios of alfalfa and corn silage to satisfy the forage requirement and analyze these rations at three levels of production.

Structural Change of the Western U.S. Alfalfa Hay Market:

In the initial estimation of the structure of the Western U.S. alfalfa hay market, the following were included as variables: milk and feeder cattle prices (both the current year and one year lagged), alfalfa exports, beef and dairy cow inventory, ending alfalfa hay stocks, alfalfa quality, substitute commodity prices, costs and a structural change dummy as shown in equation 2.

$$\begin{gathered} Market\ Price_{st} = C + M\ Price_{st} + M\ Price(-1)_{st} + F\ Price_{st} + F\ Price(-1)_{st} + \\ Exports_{st} + BeefI_{st} + DairyI_{st} + HStocks_{st} + Alfalfa_{st} + Quality_{st} + C\ Price_{st} + \\ Costs_{st} + Structure\ Dummy_{st} + e \end{gathered} \tag{2}$$

Correlograms were examined for each price variable. It was found that they were cointegrated, which allows us to estimate the variables in levels, meaning that nominal values can be use and don’t have to convert to real values or take the first difference. Correlograms for each variable can be seen in Appendix B.

The coefficient, standard error, t-statistic and p-value for each variable used in the initial regression are shown below in table 8. Lagged feeder price, alfalfa production and beef inventory were the only insignificant variables at a 10% significance level. The Adjusted R-squared was 0.76. This is a measure of the percentage of variation of the dependent variable around its mean that can be explained by the independent variables in the regression. It is also called the overall fit of the equation. The F-statistic was 100.94, with a p-value of near 0%. An F-value this large suggests there is a near 0% probability (p-value) that the independent variables are insignificant in explaining movement in the hay price. The sum of squared residual (SSR) for this equation is 1503.7. The SSR represents the sum all of the squared deviations and is mostly used to show how close the mean of the estimated equations is to the actual data points.

Low t-statistics are seen for multiple variables, indicating that multicollinearity could be a problem. Correlations between the variables were compared to look for initial signs of multicollinearity and can be found in the Appendix A. Any correlations above 0.8 were deemed to be sufficiently high to verify using VIF calculations. The only correlation coefficient that high was between alfalfa production and dairy inventory at 0.841. In order to calculate a VIF, it is necessary to regress each of these independent variables, one at a time, against all the other independent variables in the model, as was discussed in the methods chapter.

Table 8 Initial Model: Alfalfa Price as a Function of the Following Variables

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-4.928	1.697	-2.904	0.004
COMMODITY_PRICE	1.083	0.254	4.255	0
FEEDER_PRICE	2.14	0.79	2.721	0.007
FEEDER_PRICE(-1)	-0.83	0.89	-0.936	**0.350**
MILK_PRICE	0.404	0.072	5.575	0
MILK_PRICE(-1)	0.307	0.066	4.677	0
COSTS	0.01	0.003	3.096	0.002
PRECIPITATION	-0.131	0.047	-2.789	0.006
EXPORTS	0.091	0.027	3.359	0.001
HAY_PRODUCTION	-0.04	0.11	-0.328	**0.743**
ENDING_STOCKS	-0.021	0.003	-6.489	0
DAIRY_INVENTORY	0.70	0.42	1.688	0.092
BEEF_INVENTORY	-0.001	0.005	-0.195	**0.846**
STRUCTUAL_DUMMY	0.855	0.244	3.499	0.001

Once these regressions have been run, then the VIF's can be calculated using the formula in equation 3 where R^2_i is the auxiliary regression R^2:

$$VIF(\beta_k) = \frac{1}{1 - R_i^2} \tag{3}$$

The two calculated VIFs for alfalfa production and dairy inventory were 5.16 and 4.41, respectively. While there are no formal critical VIF values for severe multicollinearity, the value suggested by Studenmund (2011) is any VIF greater than 5. Hence, it appears alfalfa production is contributing severe multicollinearity to the model. As was outlined in the previous chapter, there were three options when severe multicollinearity was found; do nothing, drop a redundant variable or increase the sample size of the dataset. Given in this instance, the calculated VIF for alfalfa production was not much larger than the suggested rule of thumb, a test of joint insignificance was done including the other insignificant variables to see if alfalfa production was to remain in the regression.

The regression was rerun after dropping the insignificant variables at the 10% level of significance. The results from that regression are found in below in table 9. With the revised model, all the variables were significant at the 10% level. The adjusted R-squared was 0.76 and the F-statistic was 131.78, with a p-value of near 0%, indicating that there is near a zero probability that all of the variables in this equation are insignificant. The sum of squared residuals was 1506.5. The complete Eviews output of results for tables 8 and 9 can be found in Appendix C.

Table 9 Final Model: Alfalfa Price as a Function of the Following Variables

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-5.386	1.553	-3.468	0.001
COMMODITY_PRICE	1.057	0.248	4.262	0.000
FEEDER_PRICE	1.64	0.50	3.255	0.001
MILK_PRICE	0.415	0.071	5.855	0.000
MILK_PRICE(-1)	0.314	0.065	4.848	0.000
COSTS	0.009	0.003	2.983	0.003
PRECIPITATION	-0.127	0.046	-2.744	0.006
EXPORTS	0.093	0.026	3.618	0.000
ENDING_STOCKS	-0.022	0.003	-7.363	0.000
DAIRY_INVENTORY	0.56	0.29	1.955	0.051
STRUCTUAL_DUMMY	0.806	0.237	3.406	0.001

An F-test was performed to check for joint significance of the irrelevant variables. The F-test compares the overall fit of the two equations to determine if the omitted variables jointly contribute to improving the overall equation fit. The null hypothesis is that there is no joint significance of the variables, with the alternative hypothesis being there is joint significance. The equation for the restricted/unrestricted F-test is equation

4, with the null hypothesis represented by equation 5 and the alternative hypothesis given as equation 6.

$$F = \frac{(RSSm - RSS)/M}{RSS/(N - K - 1)} \tag{4}$$

$$H_o\!: \beta_1 Feeder\ Price_{-1} = \beta_2 Beef_I = \beta_3 Alfalfa_{Production} = 0 \tag{5}$$

$$H_A\!: otherwise \tag{6}$$

The calculated restricted/unrestricted F-test was 0.348, while the critical F-test value was 2.08 at the 10% level (Wooldridge 2006). Since the critical F-test is larger than the calculated F-test, we would fail to reject the null hypothesis, suggesting that the excluded variables are non-significant. While initial examination of the theory of alfalfa markets suggested the need for the insignificant variables, the insignificant variables were removed based on the following criteria. The Alfalfa production variable showed signs of multicollinearity with the dairy inventory variable above indicating a potential problem with this variable. Also, the ending stocks should reflect changes in production, and may even be more material in the current year's price than any subsequent hay production. Non-significant lagged feeder price suggested that most of the effects were captured by the present value, so the lagged price was excluded. It was surprising that beef inventory was non-significant, but closer examination of the data revealed that there was very little variation in the data. Furthermore, beef production has been much less reliant on alfalfa hay production than has dairy production. Thus, the second regression was used for the analysis of structural change.

Since the structural dummy variable (or intercept shifter) was significant, the Chow-test could be used to ascertain if there had been a structural change. As noted in the methodology section, the Chow-test is used by dividing the data set into two sub-sets, in this case based on the visual appearance of a structural change in alfalfa hay exports circa 1994. The data set was divided into two sub groups, the first from 1980 to 1994 the second from 1994 to 2012 (as illustrated by figure 2 in the data section). Two regressions were run, each based on the time frame just noted. The two regressions for groups 1 and 2 are found below in table 10 and 11. The complete Eviews output of results for tables 10 and 11 can be seen in Appendix C.

Table 10 Chow-test Group 1 Regression Results

OBSERVATIONS		167		
SUM SQUARED RESD.		224.98		
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	2.35	2.237	1.051	0.295
COMMODITY_PRICE	0.449	0.325	1.381	0.169
FEEDER_PRICE	2.15	0.54	3.954	0
MILK_PRICE	0.38	0.167	2.269	0.025
MILK_PRICE(-1)	-0.089	0.152	-0.585	0.559
COSTS	-0.011	0.009	-1.241	0.217
PRECIPITATION	-0.048	0.049	-0.976	0.331
EXPORTS	0.223	0.157	1.422	0.157
ENDING_STOCKS	-0.015	0.003	-4.546	0
DAIRY_INVENTORY	0.75	0.33	2.271	0.025

Notes: Group one includes the data for the years between 1980-1994

Table 11 Chow-test Group 2 Regression Results

OBSERVATIONS		234		
SUM SQUARED RESD.		997.07		
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-5.728	2.075	-2.761	0.006
COMMODITY_PRICE	1.245	0.329	3.787	0
FEEDER_PRICE	0.03	0.82	0.036	0.971
MILK_PRICE	0.504	0.084	6.003	0
MILK_PRICE(-1)	0.414	0.077	5.396	0
COSTS	0.009	0.004	2.256	0.025
PRECIPITATION	-0.137	0.065	-2.103	0.037
EXPORTS	0.09	0.031	2.947	0.004
ENDING_STOCKS	-0.03	0.005	-6.274	0
DAIRY_INVENTORY	0.18	0.41	0.45	0.653

Notes: Group two includes the data for the years between 1994-2012

The Chow-test is calculated following the notation in equation 10 by using the pooled regression SSR (SSRp) and the SSRs from the two sub-set regressions (SSR1 and SSR2). Equation 11 states the null hypothesis, i.e., group one and group two are the same and no structural change has occurred. Equation 12 gives the alternative hypothesis that a structural change has occurred.

$$F = \frac{SSRp - (SSR1 + SSR2)}{SSR1 + SSR2} * \frac{N - 2(K + 1)}{k + 1} \qquad (7)$$

$$H_o: \beta_{Group1} - \beta_{Group2} = 0 \qquad (8)$$

$$H_A: otherwise \qquad (9)$$

The calculated value of the Chow-test for these two regressions was 10.62. The critical value is 1.63 at the 10% level (Wooldridge 2006). Thus we rejected the null-hypothesis that there was no structural change and supported the alternative hypothesis that a structural change occurred in the Western U.S. alfalfa hay market beginning in 1994.

Percentage changes between the independent variables and the dependent variable were calculated and are provided in table 12. These were obtained by inserting the mean value for each independent variable into the estimated equation, then increasing each variable by 1% to measure the change in alfalfa price. Milk price in the current year, followed by last year's milk price, yielded the largest percent changes in alfalfa price, with alfalfa exports being second to last, only followed by the yearly inventory of dairy cows. A one percent increase in the mean of each variable is shown, followed by the resulting increase in alfalfa price. As an example, for every 5015 tons change in ending stocks, alfalfa price moves $1.07 per ton correspondingly.

Table 12 Percent Changes in Alfalfa Price

Variable	% Change	1% Change in Var.	Resulting Change in Alfalfa Price
Ending Stocks (1,000,000 tons)	-1.07%	5015	$1.07
Dairy Inventory (10,000 cows)	0.06%	3983	$0.06
Commodity Price ($/Bushel)	1.05%	0.028	$1.05
Feeder Price ($/Cwt)	1.63%	0.9238	$1.63
Milk Price ($/Cwt)	4.12%	0.14	$4.12
Milk Price $^{-1}$ ($/Cwt)	3.12%	0.14	$3.12
Costs, PPI (Fuel Price Index)	0.90%	1.17	$0.90
Precipitation (in.)	-0.13%	0.00345	$0.13
Exports ($1,000,000)	0.09%	224500	$0.09

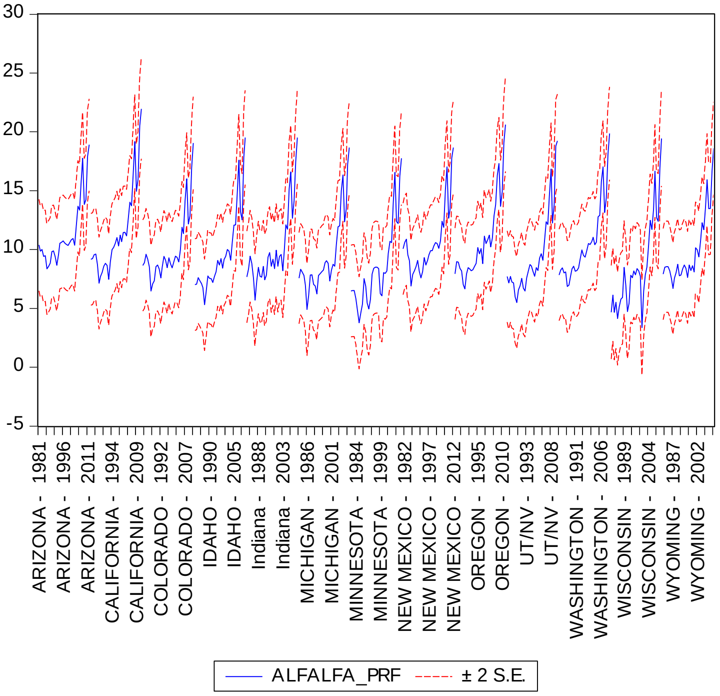
Notes: 1% Change in Var. represents a 1% change at the mean of each variable. The Resulting Change in Alfalfa Price is how alfalfa price will change.

An in-sample forecast was done next to define how well the model was forecasting alfalfa hay prices, the results of which can be found below in figure 3. A graph of the estimated price compared to the actual price can be seen in figure 4. Four different measurements were taken and reported including the forecast root mean squared error (RMSE), mean absolute error (MAE), mean absolute percent error (MAPE), and the Theil’s inequality coefficient. RMSE measures the square root of the average of the sum of squares of the errors. MAE calculates the average of the sum of absolute value of deviations from the forecast mean value for each time period. The Theil’s inequality coefficient is used to compare forecast results across methods used. These measures of accuracy are used differently. RMSE penalizes models with larger prediction errors more than MAE. (Jiang and Hayenga 1954).

The MAE was 14.4. Since the price data were divided by 10 for estimation purposes this MAE means that we were predicting the sample alfalfa price within $14.40 of its actual price along the entire time period of the estimation. The MAPE coefficient is 14.87. The MAPE is in percentage terms implied the estimated value was 14.87% of the actual value. The average value for alfalfa price is $99.90, so the estimated equation is predicting alfalfa price within $14.85 of its actual value over the entire estimation period. In two previous studies, forecasts for alfalfa hay were formulated. The resulting Theil’s inequality coefficient were 0.72 for the econometric price forecasting model and 0.76 for the ARIMA model done by Konyar and Knapp (1988). The Theil’s inequality was 0.15 and 0.08 in for the ARIMA forecast and the combined econometric and ARIMA model, respectively, for Myer and Yanagida (1984). For the in sample econometric forecast that was performed on this dataset the Theil’s inequality was 0.08. When the estimated alfalfa price was graphed with the actual alfalfa hay price, the estimated values followed actual values quite well as shown in figure 4. Minnesota and New Mexico appeared to have the most variation (which is a measure of risk) between the predicted and actual.

There is evidence that a structural change occurred in the Western U.S. alfalfa hay market in 1994 when alfalfa exports began to increase. One problem that the model exhibits is serial correlation. As was pointed out in the methodology chapter, serial correlation causes bias in the standard errors and, thus, affects hypothesis testing.

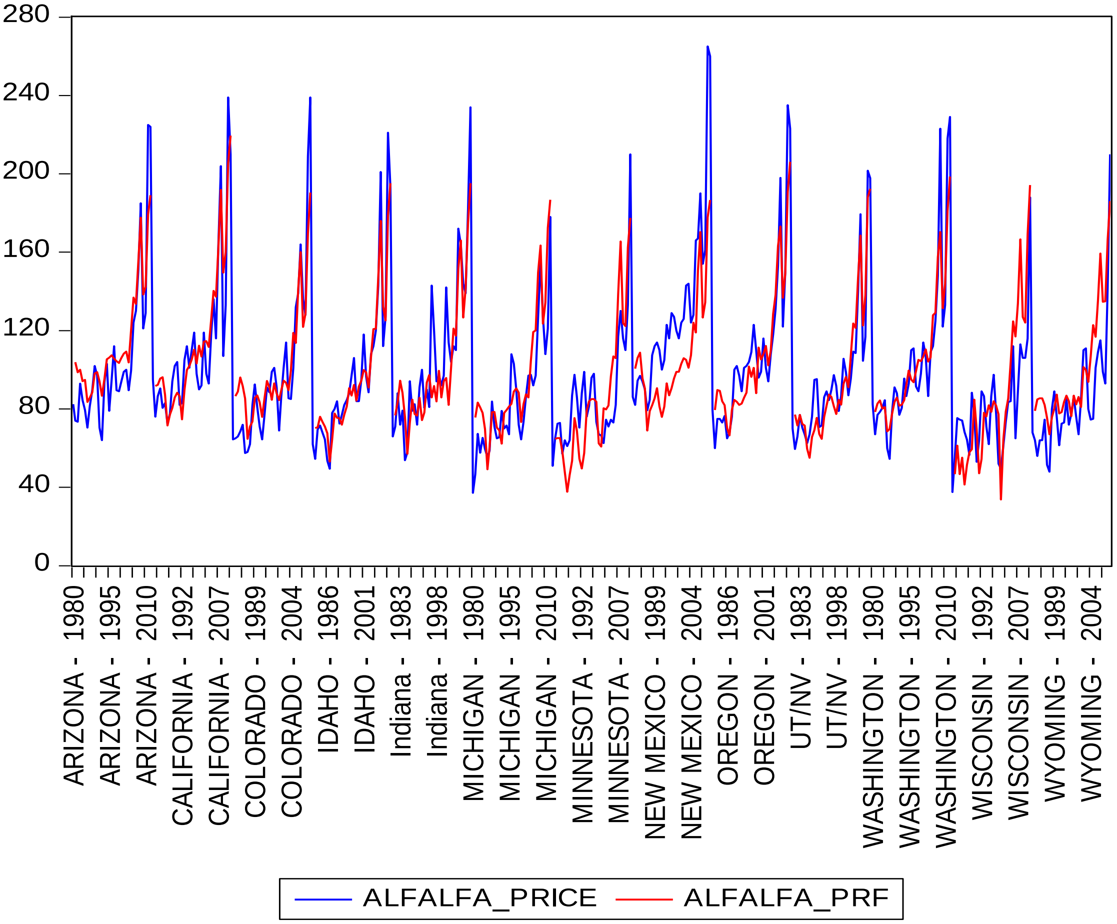
Figure 3 Forecast Performance Results



Forecast: ALFALFA_PRF
Actual: ALFALFA_PRICE
Forecast sample: 1 429
Adjusted sample: 1 429
Included observations: 416

Root Mean Squared Error	1.902977
Mean Absolute Error	1.440725
Mean Abs. Percent Error	14.87478
Theil Inequality Coefficient	0.088515
Bias Proportion	0.000000
Variance Proportion	0.066899
Covariance Proportion	0.933101

Figure 4 Forecast and Actual Alfalfa Hay Prices



Since the objectives of this thesis were to test for structural change and the t-statistics were quite strong, serial correlation was not believed to affect the outcomes of the analysis, but it should be taken into if other uses of the model were made. By calculating the percentage changes from the regression results, it has been shown that milk price has been highly correlated with the alfalfa hay market, which is expected considering most high quality alfalfa is fed to dairy cows to produce milk.

IFSM Average Utah Dairy

The simulation results showing mean and standard deviation (SD) from the IFSM are reported below for forage production, forage purchased and sold, income from feed sales, net costs for feed and milk production, milk income, net returns per cow and net returns over feed costs, animal purchases and expenses, returns to management, cost of feed production per ton, and overall feed costs per ton (which includes storage, shrinkage, and feeding).

The rations represent the different amounts of alfalfa hay and corn silage being harvested and fed to the dairy herd. All things were held constant across all the simulations except the amount of alfalfa fed to the dairy herd, the size of the corn silage storage, acreage in corn or alfalfa, and milk production. It should be noted that the replacement heifers' rations were held constant even though the mature animal ration was allowed to vary. Alfalfa hay and corn silage were varied in the ration in order to determine which amount of each forage would provide the best economic results. For the three levels of production, alfalfa hay represented 25%, 50%, and 75% of the forage DM requirement, respectively, with corn silage fulfilling the remainder of the forage DM requirement.

Corn silage storage was sized to the expected amount of feed required for the ration. This was needed because of the nature in which the simulation operates. The simulation is set to fill the storage available for corn silage, then proceeds to fill the storage available for high moisture corn, with the remainder harvested as dry corn. Storage was varied to ensure that once enough corn silage was harvested, the balance of the corn planted would go to high moisture grain corn. Acreage of each forage was varied in each simulation to provide the required forage type. Finally, milk production was varied to determine if the forage ration was sensitive to production levels and to provide broader relevance to different production levels in the Utah region. As some of these assumptions build upon each other, a degree of variability is to be expected in the results. For instance, it was estimated how much DM intake would be required for a given level of production, which was then used to estimate the needed levels of crop production. This was then used to establish how much corn silage storage was needed. Essentially, three levels of assumptions were made off the initial assumption. The simulations results are grouped by production level (26,700 lbs., 22,500 lbs., and 18,300 lbs, respectively) are shown in tables 13, 14, and 15. This particular order is used to better illustrate what happens to costs and returns as the crashing changes and as the dairies become smaller.

In noting the results, the nine simulations will be discussed simultaneously. Generally when a production level is referenced, the three different ratios of forage for that level of production are discussed. We will reference the following simulations by what level of production was simulated, then from left to right as: 1 representing the simulation where hay is 25% of the forage requirement, 2 as the simulation that is 50% hay and, finally, 3 as the simulation that has 75% hay. The discussion will be intentionally broad, looking at general trends over all simulations. Because we have simulated a “typical” operation in Box Elder County, Utah, only the general trends are considered. All percentages discussed in reference to alfalfa and corn silage as part of the rations were used as percent of forage requirement.

Table 13 Simulation at 26,700 lbs. Milk Production for Three Rations

	25% Alfalfa Hay		50% Alfalfa Hay		75% Alfalfa Hay	
	Mean	SD	Mean	SD	Mean	SD
Alfalfa, Acres	200		290		360	
Corn, Acres	500		410		340	
High Quality Alfalfa, Tons	680	121	977	165	1,205	223
Low Quality Alfalfa, Tons	107	115	175	159	225	208
Corn Silage, Tons	3,415	4	2,409	2	1,709	3
HM Corn Production, Tons	469	115	580	95	608	79
Dry Corn Production, Tons	0	0	0	0	0	0
Canola Seed Purchased, Tons	819	28	624	29	475	25
Forage Purchased, Tons	0	0	0	0	334	115
Forage Sold, Tons	994	81	166	104	0	0
Grain Purchased, Tons	285	160	287	133	430	102
Grain Sold, Tons	0	0	0	0	0	0
Income from Feed Sales, $	103,428	10,987	38,638	2,125	29,035	3,118
Net Feed Costs, $	1,053,266	19,925	1,093,293	30,071	1,068,134	18,090
Net Cost per Unit of Milk Income	10	0	10	0	10	0
Net Cost as Portion of Milk	58	1	59	2	59	1
Income from Milk Sales, $	1,802,784	0	1,802,784	0	1,802,784	0
Net return Over Feed Costs, $	749,519	19,925	708,412	28,823	734,650	18,090
Net return per Cow	1,874	50	1,852	36	1,837	45
Animal Purchases and Expenses, $	143,512	0	143,512	0	143,512	0
Income from Animal Sales, $	198,519	0	198,519	0	198,519	0
Return to Management, $	297,664	19,831	288,980	14,792	276,731	18,548
Crop Production Costs:						
Alfalfa Hay, $	138	9	127	6	109	8
Corn Silage, $	78	3	98	3	97	3
High Moisture Corn, $	133	11	146	12	129	11
Feed Costs:						
Alfalfa Hay , $	166	9	145	7	142	7
Corn Silage, $	98	3	108	3	118	3
High Moisture Corn, $	143	15	151	12	139	11

Note: Results from IFSM simulation assuming 26,700 lbs. milk production

Table 14 Simulation at 22,500 lbs. Milk Production for Three Rations

	25% Alfalfa Hay		50% Alfalfa Hay		75% Alfalfa Hay	
	Mean	SD	Mean	SD	Mean	SD
Alfalfa, Acres	200		300		370	
Corn, Acres	500		400		330	
High Quality Alfalfa, Tons	680	121	1,007	174	1,233	227
Low Quality Alfalfa, Tons	107	115	180	167	223	212
Corn Silage, Tons	3,006	4	2,050	3	1,709	3
HM Corn Production, Tons	661	114	692	90	568	77
Dry Corn Production, Tons	2	8	2	6	0	0
Canola Seed Purchased, Tons	0	0	237	103	345	111
Forage Purchased, Tons	712	23	521	27	387	26
Forage Sold, Tons	464	85	0	0	0	0
Grain Purchased, Tons	0	0	0	0	143	100
Grain Sold, Tons	308	155	190	115	0	0
Income from Feed Sales, $	115,509	33,604	61,961	26,440	28,274	5,048
Net Feed Costs, $	936,111	27,055	946,088	22,476	968,961	18,675
Net Cost per Unit of Milk	10	0	11	0	11	0
Net Cost as Portion of Milk Income	62	2	62	2	64	1
Income from Milk Sales, $	1,519,200	0	1,519,200	0	1,519,200	0
Net return Over Feed Costs, $	583,089	27,055	573,112	22,476	550,239	18,675
Net return per Cow, $	1,458	68	1,433	56	1,376	47
Animal Purchases and Expenses, $	143,512	0	143,512	0	143,512	0
Income from Animal Sales, $	198,519	0	198,519	0	198,519	0
Return to Management, $	151,856	26,872	138,810	22,518	114,110	19,175
Crop Production Costs:						
Alfalfa Hay, $	137	9	116	8	108	8
Corn Silage, $	82	3	91	3	97	3
High Moisture Corn, $	125	12	125	10	103	11
Feed Costs:						
Alfalfa Hay , $	163	9	147	8	141	7
Corn Silage, $	102	3	112	3	118	3
High Moisture Corn, $	135	12	135	10	140	11

Note: Results from IFSM simulation assuming 22,500 lbs. milk production

Table 15 Simulation at 18,300 lbs. Milk Production for Three Rations

	25% Alfalfa Hay		50% Alfalfa Hay		75% Alfalfa Hay	
	Mean	SD	Mean	SD	Mean	SD
Alfalfa, Acres	200		300		400	
Corn, Acres	500		400		300	
High Quality Alfalfa, Tons	680	121	1,007	174	1,323	228
Low Quality Alfalfa, Tons	107	115	180	167	262	224
Corn Silage, Tons	2,877	4	2,050	3	1,367	2
HM Corn Production, Tons	712	104	692	90	607	72
Dry Corn Production ,Tons	8	24	2	6	0	0
Canola Seed Purchased, Tons	0	0	297	104	643	106
Forage Purchased, Tons	576	25	387	28	280	23
Forage Sold, Tons	283	79	0	0	0	0
Grain Purchased ,Tons	0	0	0	0	0	0
Grain Sold, Tons	643	151	464	114	215	90
Income from Feed Sales, $	176,347	34,036	120,244	27,154	62,175	21,956
Net Feed Costs, $	817,429	27,386	832,241	22,568	871,029	21,916
Net Cost per Unit of Milk	11	0	11	0	12	0
Net Cost as Portion of Milk Income	66	2	67	2	71	2
Income from Milk Sales, $	1,235,616	0	1,235,616	0	1,235,616	0
Net return Over Feed Costs, $	418,187	27,386	403,375	22,586	364,587	21,916
Net return per Cow, $	1,045	68	1,008	56	911	55
Animal Purchases and Expenses, $	143,512	0	143,512	0	143,512	0
Income from Animal Sales, $	198,519	0	198,519	0	198,519	0
Return to Management, $	8,681	27,361	-9,108	22,619	-51,205	22,509
Crop Production Costs:						
Alfalfa Hay, $	137	9	116	8	105	6
Corn Silage, $	83	3	91	3	106	3
High Moisture Corn, $	122	11	124	10	128	11
Feed Costs:						
Alfalfa Hay , $	163	9	147	7	141	6
Corn Silage, $	103	3	112	3	128	3
High Moisture Corn, $	132	11	134	10	138	11

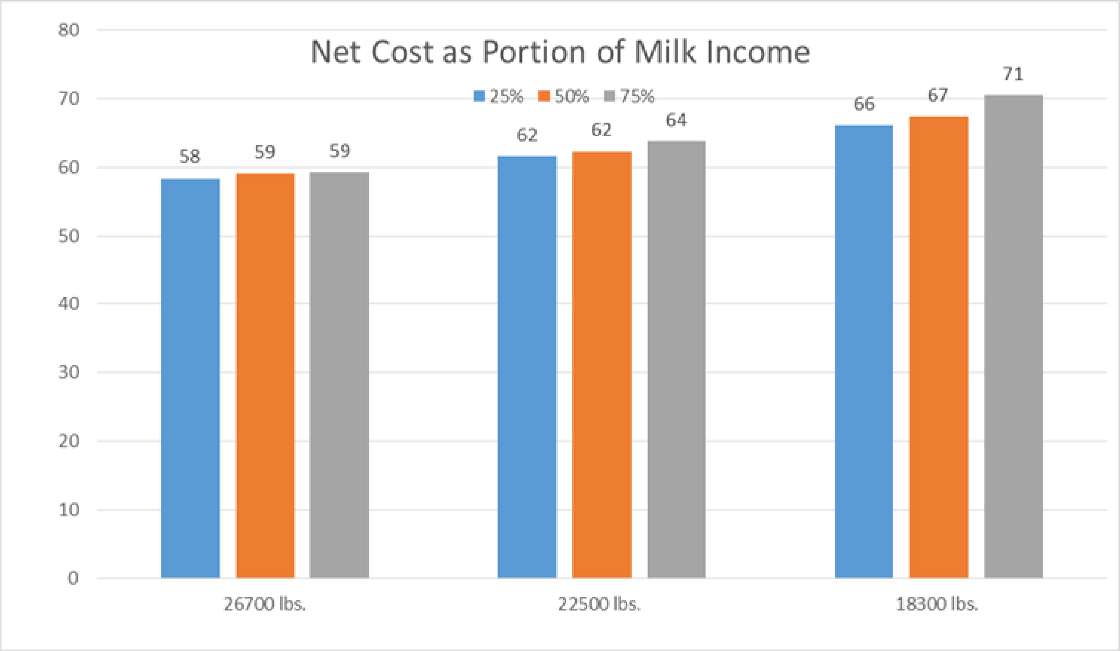
Note: Results from IFSM simulation assuming 18,300 lbs. milk production

The simulation results are found in tables 13 through 15, the mean value of the simulation is first reported with the SD given next. The SD for the production components represent the variation in values over the 25 years simulated and can be used to represent the level of risk. When looking at the forage production yields, the SD of alfalfa is relatively high when compared to the SD of corn silage and high moisture corn. The production of alfalfa hay had a higher level of risk than corn silage or high moisture corn under these simulations. Furthermore, production of high moisture corn had a higher SD (or level of risk) than corn silage.

In the simulation results, average values for forage purchased and sold and grain purchased and sold were reported in tons. While not reporting specifically what was sold or purchased, forage sales indicated that sufficient, or even excess, land was present. Over all the simulations, as alfalfa hay was increased in the ration, it became harder to provide for the forage requirements of the animals. The results of forage having to be purchased while some is sold reflects a misallocation of assets, but the general trend was that it was easier to meet the forage requirements on 700 acres when alfalfa represents only 25% of the forage grown and this trend is present at all three levels of milk production, though at different magnitudes. The trend is also reflected in the income from feed sales. At all levels of production, feed sales decreased as more alfalfa hay was fed in the ration.

At all levels of production, net feed costs increased as more alfalfa hay was incorporated into the diet as illustrated in figure 5. As expected, net cost per unit of milk and net cost as the proportion of milk income decreased as milk production increased, as can be seen in tables 13,15, and 15, but is highlighted in figure 5 below.

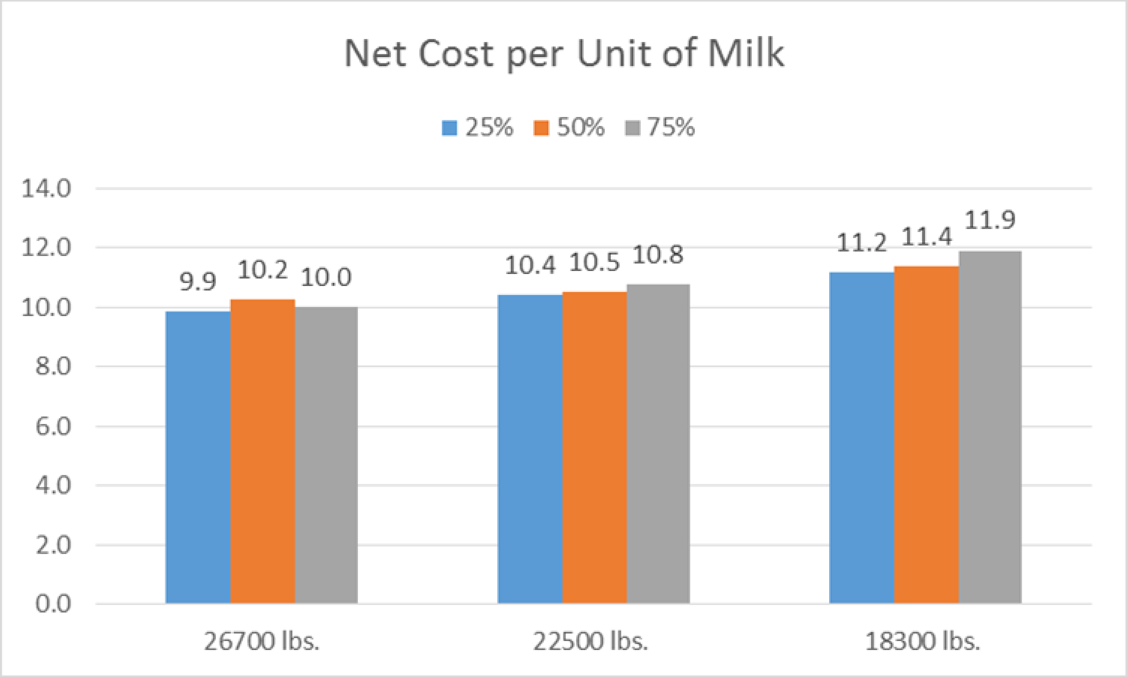
Figure 5 Net Cost as Portion of Milk Income



Note: % represents the present of alfalfa hay in the ration

Figure 7 contains the graph for net return per cow. Net returns per cow increase as alfalfa is replaced by corn silage in the ration, with returns per cow increasing the most at the lowest level of production. Figure 8 illustrates returns to management and includes the total profit from crop sales and the dairy operation. It gives insights into how changes to the ration will affect the profitability of the operation. It should be noted that increasing milk production increased total returns to management, as would be expected, as illustrated in figure 8.

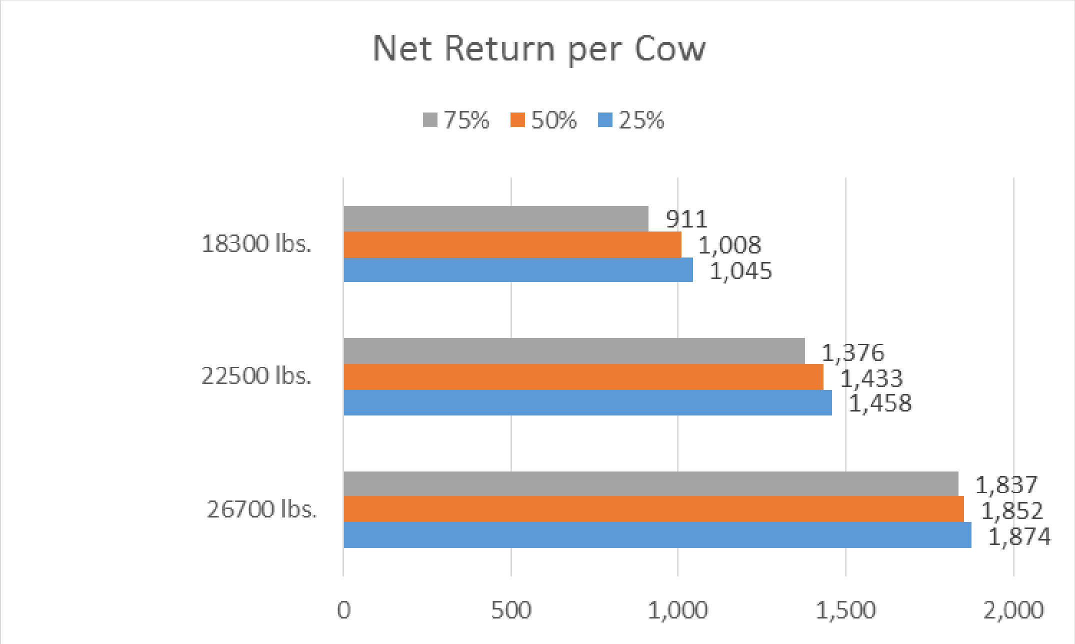
Figure 6 Net Cost per Unit of Milk



Note: % represents the present of alfalfa hay in the ration

It is important to note is the variation expressed within the three production simulations. At the 26,700 production level, there was a 7% increase in return to management as alfalfa decreased in the ration, but for the 22,500 lbs. level of milk production, returns to management increased 25% as alfalfa decreased from 75% of the ration to 25%. The greatest increase occurred at the 18,300 lbs. production level, with returns to management increasing by 86%. From these simulations, it is apparent that while decreasing alfalfa in the ration increased profits in all simulation, the greatest benefit was evident at lower levels of milk production (shown in reverse order for expository purposes).

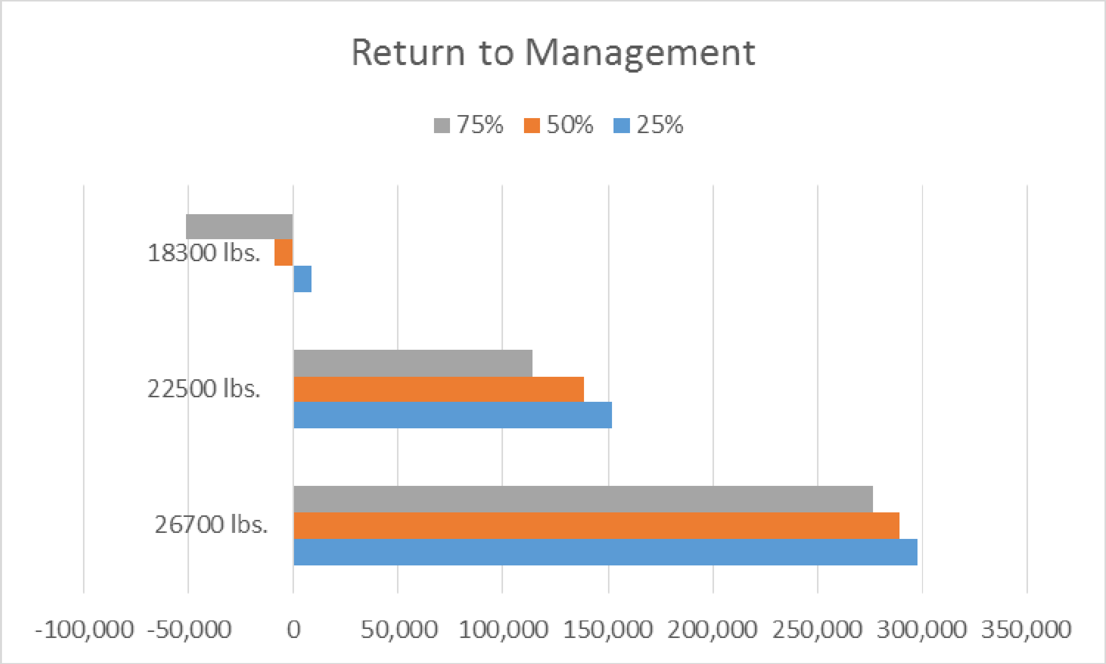
Figure 7 Net Return per Cow



Note: % represents the present of alfalfa hay in the ration

Costs of production provides an estimated cost of producing each crop grown. Economies of scale in crop production were also visible from the simulation reports. Cost of alfalfa production decreased by an average of $30 per ton across the simulations as production increased. If taken on a DM basis at 6.5 tons per acre, this would be an average improvement of $195 per acre. Costs of corn silage production decreased by $19 per ton or $199.50 per acre as production increased. Because of the way in which the simulation was performed, the figures for high moisture grain corn were not accurately calculated.

Figure 8 Returns to Management



Note: % represents the present of alfalfa hay in the ration

Feed Costs included those associated with labor, storage costs, and shrinkage. These were averaged across the simulations to give an average amount per ton that it cost to store feed. On average, it costs $29, $20, and $12, respectively, to store alfalfa hay, corn silage, and high moisture grain corn per ton. Economies of scale were evident, with some savings being generated through storing larger quantities of feed.

CHAPTER 7

CONCLUSION AND RECOMMENDATIONS

Conclusion

The goals of this thesis were to identify whether structural changes in the alfalfa market had occurred, and in light of those changes, determine what ratios of alfalfa hay and corn silage should be grown and fed on an average Utah dairy farm in Box Elder County, Utah, to generate the greatest level of profits. Specific objectives were to: 1) identify structure change in the alfalfa hay market, 2) find which components of demand have influenced the change in alfalfa price and to what magnitude, 3) to evaluate the financial performance of the average Utah dairy operation when alfalfa hay represented a) one-third, b) one-half and c) two-thirds of the forage DM in the dairy ration, with corn silage representing the balance, and 4) evaluate the differences the effects these three rations had on the economic and financial performance of the operation at three levels of production.

Evidence of structural change was found using regression analysis and the Chow test, supporting the hypothesis that the Western U.S. alfalfa hay market has undergone a structural change. Components contributing to alfalfa price changes were identified and the percentage changes attributable to each of these components estimated. As the literature review pointed out, when dairy cows were fed a balanced ration, milk production was not affected by the amount of alfalfa hay or corn silage used to meet the forage requirement. When all processes were analyzed economically, profits were increased under a corn silage production and feeding program for Utah dairies under all simulations, but with a greater percentage effect at lower levels of milk production.

While structural change was tested for in 1994, it is also evident from the export graph that the slope changed again in 2006, suggesting that a second structural change may have occurred in the alfalfa export market. This date corresponds to when ethanol production expanded in the U.S. Given the results of this Dissertation, the argument could be made that increasing ethanol production has again changed the market structure, though it is likely not head as significant a role in the Western US as in the Midwest. The argument comes from the calculated percent changes. Commodity prices show a 1.05% change in alfalfa price. So if the mean commodity price of $2.79 (bushels) used a 2.79 cent increase in corn, barley, and wheat price would increase alfalfa price 1.05% or $1.05 using the mean alfalfa price. Corn price peaked at $7.62 per bushel or an increase of 273% this could represent another structural change in the market structure.

Improvement on this thesis is not limited to further examination for structural change. Serial correlation was a problem in the regression analysis causing unreliability in the hypothesis testing. The resolution of this problem should improve the estimated equation and increase forecasting ability. Unfortunately, serial correlation is not easily dealt with when using panel data.

It may also be beneficial to make some changes to the IFSM. One of the major drawbacks of the simulation was the inability to know which forage was purchased and which was sold. Knowing this would have given us the ability to accurately estimate how many acres are needed for each ration.

The final recommendation is that the results of this thesis could also be expanded by sensitivity analysis of yield and cost of the crops in the ration. Nine simulations were compared to see how forage crop ratio effected returns to management. Prices of crops were not varied to determine a cost range for each forage ratio nor was yield changed. Variation of these two inputs would likely affect what is the optimal ratio of alfalfa and corn silage.

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APPENDICES

APPENDIX A

DESCRIPTIVE STATISTCS

	Beef I	Dairy I	Milk Price	Alfalfa Production	Market Price	Feeder price
Mean	47.98	3.98	13.95	32.40	10.00	9.24
Standard Error	1.12	0.24	0.11	0.96	0.19	0.14
Median	49.30	1.81	13.21	25.86	9.01	9.09
Mode	19.50	1.00	12.80	12.50	11.20	11.80
Standard Deviation	23.12	4.88	2.25	19.82	3.92	2.89
Sample Variance	534.73	23.86	5.05	392.87	15.39	8.33
Kurtosis	-0.78	1.87	1.11	1.77	3.35	1.04
Skewness	0.20	1.74	1.33	1.35	1.74	0.70
Range	108.90	18.88	10.80	103.72	22.78	19.42
Minimum	7.10	0.04	10.60	9.68	3.72	2.99
Maximum	116.00	18.92	21.40	113.40	26.50	22.42
Sum	20584.70	1708.71	5984.51	13898.70	4288.83	3963.24
Count	429.00	429.00	429.00	429.00	429.00	429.00

	C Price	Precipitation	Hay Stocks	Exports	Costs	Structural Dummy
Mean	2.79	0.34	50.15	2.25	117.53	0.58
Standard Error	0.02	0.10	2.33	0.24	4.03	0.02
Median	2.74	0.12	36.80	0.00	83.40	1.00
Mode	#N/A	0.18	40.00	0.00	85.80	1.00
Standard Deviation	0.51	2.12	48.33	4.99	83.44	0.49
Sample Variance	0.26	4.50	2335.71	24.90	6961.46	0.24
Kurtosis	-0.42	2.00	9.21	24.18	0.79	-1.91
Skewness	0.20	0.72	2.55	4.18	1.44	-0.31
Range	2.50	16.40	365.70	45.66	278.70	1.00
Minimum	1.70	-6.42	1.20	0.00	47.40	0.00
Maximum	4.19	9.98	366.90	45.66	326.10	1.00
Sum	1195.04	147.87	21515.50	963.23	50421.80	247.00
Count	429.00	429.00	429.00	429.00	429.00	429.00

CORRELATIONS

	ALFALFA _PRICE	COMMODITY _PRICE	FEEDER _PRICE	MILK _PRICE	COSTS	PRECIPITATION
ALFALFA_PRICE	1.000	0.504	0.559	0.675	0.789	-0.204
COMMODITY_PRICE	0.504	1.000	0.191	0.322	0.523	-0.141
FEEDER_PRICE	0.559	0.191	1.000	0.525	0.680	-0.177
MILK_PRICE	0.675	0.322	0.525	1.000	0.783	-0.037
COSTS	0.789	0.523	0.680	0.783	1.000	-0.117
PRECIPITATION	-0.204	-0.141	*N/A*	-0.037	-0.117	1.000
EXPORTS	0.450	0.318	0.233	0.180	0.375	-0.114
ENDING_STOCKS	-0.354	-0.283	0.114	-0.110	-0.126	0.081
DAIRY_INVENTORY	-0.019	-0.081	0.231	-0.042	0.042	-0.001
BEEF_INVENTORY	-0.041	0.131	-0.200	-0.162	-0.113	-0.081
Alfalfa_PRODUCTION	-0.183	-0.173	0.028	-0.170	-0.091	0.082

	EXPORTS	ENDING _STOCKS	DAIRY _INVENTORY	BEEF _INVENTORY	ALFALFA _PRODUCTION
ALFALFA_PRICE	0.450	-0.354	-0.019	-0.041	-0.183
COMMODITY_PRICE	0.318	-0.283	-0.081	0.131	-0.173
FEEDER_PRICE	0.233	0.114	0.231	-0.200	0.028
MILK_PRICE	0.180	-0.110	-0.042	-0.162	-0.170
COSTS	0.375	-0.126	0.042	-0.113	-0.091
PRECIPITATION	-0.114	0.081	-0.001	-0.081	0.082
EXPORTS	1.000	-0.175	0.358	0.138	0.289
ENDING_STOCKS	-0.175	1.000	0.562	-0.212	0.624
DAIRY_INVENTORY	0.358	0.562	1.000	-0.101	0.841
BEEF_INVENTORY	0.138	-0.212	-0.101	1.000	0.041
Alfalfa_PRODUCTION	0.289	0.624	0.841	0.041	1.000

APPENDIX B

Milk Price

```
Date: 01/31/14   Time: 13:51
Sample: 1 429
Included observations: 429
==========================================================================
 Autocorrelation   Partial Correlation        AC      PAC    Q-Stat   Prob
==========================================================================
    .|***   |         .|***   |         1   0.460    0.460   91.291  0.000
    .|*     |         .|.     |         2   0.175   -0.047   104.49  0.000
    .|***   |         .|****  |         3   0.476    0.525   202.70  0.000
    .|***   |         *|.     |         4   0.384   -0.080   266.85  0.000
    .|*     |         .|.     |         5   0.117   -0.002   272.86  0.000
    .|*     |         .|.     |         6   0.185   -0.017   287.85  0.000
    .|*     |         *|.     |         7   0.174   -0.112   301.15  0.000
    .|.     |         .|.     |         8   0.030   -0.012   301.54  0.000
    .|.     |         .|.     |         9   0.057    0.013   302.95  0.000
    .|.     |         *|.     |        10  -0.009   -0.160   302.99  0.000
    .|.     |         .|*     |        11   0.003    0.197   302.99  0.000
    .|.     |         *|.     |        12   0.003   -0.166   303.00  0.000
    .|.     |         .|*     |        13  -0.016    0.175   303.12  0.000
    .|.     |         *|.     |        14  -0.006   -0.068   303.13  0.000
    .|.     |         .|.     |        15  -0.021   -0.028   303.33  0.000
    *|.     |         *|.     |        16  -0.115   -0.137   309.30  0.000
==========================================================================
```

Feeder Price

```
Date: 01/31/14   Time: 13:52
Sample: 1 429
Included observations: 429
==========================================================================
 Autocorrelation   Partial Correlation        AC      PAC    Q-Stat   Prob
==========================================================================
    .|******|         .|******|         1   0.789    0.789   268.75  0.000
    .|****  |         *|.     |         2   0.587   -0.094   417.82  0.000
    .|***   |         .|*     |         3   0.472    0.106   514.57  0.000
    .|***   |         .|*     |         4   0.418    0.084   590.73  0.000
    .|***   |         .|.     |         5   0.379    0.032   653.26  0.000
    .|**    |         .|.     |         6   0.338    0.019   703.21  0.000
    .|**    |         *|.     |         7   0.248   -0.124   730.25  0.000
    .|*     |         *|.     |         8   0.129   -0.126   737.53  0.000
    .|*     |         .|.     |         9   0.076    0.062   740.08  0.000
    .|*     |         .|*     |        10   0.104    0.120   744.88  0.000
    .|*     |         .|.     |        11   0.146    0.067   754.34  0.000
    .|*     |         .|.     |        12   0.141   -0.029   763.19  0.000
    .|*     |         .|.     |        13   0.102   -0.028   767.86  0.000
    .|.     |         .|.     |        14   0.066   -0.001   769.78  0.000
    .|.     |         *|.     |        15   0.025   -0.080   770.05  0.000
    .|.     |         *|.     |        16  -0.018   -0.108   770.20  0.000
==========================================================================
```

Alfalfa Price

```
Date: 01/31/14   Time: 13:49
Sample: 1 429
Included observations: 429
=================================================================
   Autocorrelation     Partial Correlation      AC     PAC    Q-Stat   Prob
=================================================================
      .|***** |            .|***** |      1   0.665   0.665   191.00   0.000
      .|***   |            *|.     |      2   0.405  -0.067   261.93   0.000
      .|***   |            .|***   |      3   0.452   0.377   350.67   0.000
      .|***   |            .|.     |      4   0.475   0.056   448.66   0.000
      .|**    |            .|.     |      5   0.339  -0.064   498.76   0.000
      .|**    |            .|.     |      6   0.244  -0.001   524.88   0.000
      .|*     |            *|.     |      7   0.175  -0.148   538.37   0.000
      .|*     |            .|.     |      8   0.102  -0.060   542.98   0.000
      .|*     |            .|.     |      9   0.094   0.054   546.83   0.000
      .|*     |            .|.     |     10   0.122   0.072   553.40   0.000
      .|*     |            .|.     |     11   0.099   0.044   557.77   0.000
      .|.     |            .|.     |     12   0.040  -0.023   558.49   0.000
      .|.     |            .|.     |     13   0.016  -0.037   558.61   0.000
      .|.     |            .|.     |     14   0.044   0.014   559.48   0.000
      .|.     |            .|.     |     15   0.045  -0.029   560.40   0.000
      .|.     |            *|.     |     16  -0.013  -0.070   560.47   0.000
=================================================================
```

Commodity Price

```
Date: 01/31/14   Time: 13:50
Sample: 1 429
Included observations: 429
=================================================================
   Autocorrelation     Partial Correlation      AC     PAC    Q-Stat   Prob
=================================================================
      .|***** |            .|***** |      1   0.638   0.638   176.02   0.000
      .|***   |            .|.     |      2   0.410   0.005   248.96   0.000
      .|**    |            .|*     |      3   0.315   0.086   291.91   0.000
      .|**    |            .|*     |      4   0.289   0.094   328.37   0.000
      .|**    |            .|.     |      5   0.215  -0.040   348.46   0.000
      .|.     |            *|.     |      6   0.073  -0.139   350.76   0.000
      .|.     |            .|*     |      7   0.062   0.085   352.47   0.000
      .|.     |            .|.     |      8   0.040  -0.043   353.18   0.000
      .|.     |            *|.     |      9  -0.059  -0.144   354.73   0.000
      .|.     |            .|*     |     10  -0.035   0.133   355.28   0.000
      .|.     |            .|.     |     11   0.016   0.056   355.40   0.000
      .|*     |            .|*     |     12   0.103   0.100   360.06   0.000
      .|.     |            .|.     |     13   0.074  -0.029   362.46   0.000
      .|*     |            .|*     |     14   0.085   0.074   365.71   0.000
      .|*     |            .|*     |     15   0.166   0.080   378.01   0.000
      .|.     |           **|.     |     16   0.057  -0.234   379.44   0.000
=================================================================
```

Exports

```
Date: 01/31/14   Time: 13:53
Sample: 1 429
Included observations: 429
===================================================================================
   Autocorrelation     Partial Correlation        AC     PAC    Q-Stat    Prob
===================================================================================
     .|******|            .|******|        1   0.856   0.856   316.21   0.000
     .|*****  |            .|.     |        2   0.749   0.064   559.20   0.000
     .|*****  |            .|.     |        3   0.657   0.008   746.47   0.000
     .|****   |            .|.     |        4   0.572  -0.014   888.79   0.000
     .|****   |            .|.     |        5   0.512   0.052   1003.3   0.000
     .|***    |            .|.     |        6   0.470   0.049   1099.9   0.000
     .|***    |            .|.     |        7   0.438   0.039   1184.1   0.000
     .|***    |            .|.     |        8   0.398  -0.029   1253.8   0.000
     .|***    |            .|.     |        9   0.360  -0.010   1310.7   0.000
     .|**     |            .|.     |       10   0.308  -0.062   1352.4   0.000
     .|**     |            .|.     |       11   0.259  -0.020   1382.1   0.000
     .|**     |            .|.     |       12   0.232   0.046   1405.9   0.000
     .|*      |            .|.     |       13   0.197  -0.035   1423.1   0.000
     .|*      |            .|.     |       14   0.170  -0.000   1436.0   0.000
     .|*      |            .|.     |       15   0.147  -0.008   1445.7   0.000
     .|*      |            .|.     |       16   0.117  -0.037   1451.8   0.000
===================================================================================
```

APENDIX C

INITIAL REGRESSION

Dependent Variable: ALFALFA_PRICE
Method: Panel Least Squares
Date: 02/14/14   Time: 16:38
Sample: 1 429
Periods included: 32
Cross-sections included: 13
Total panel (balanced) observations: 416

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-4.928425	1.697045	-2.904121	0.0039
COMMODITY_PRICE	1.082820	0.254473	4.255139	0.0000
FEEDER_PRICE	0.213730	0.078559	2.720619	0.0068
FEEDER_PRICE(-1)	-0.083289	0.089027	-0.935548	0.3501
MILK_PRICE	0.403794	0.072427	5.575200	0.0000
MILK_PRICE(-1)	0.307223	0.065687	4.677061	0.0000
COSTS	0.009675	0.003124	3.096435	0.0021
PRECIPITATION	-0.131060	0.046998	-2.788652	0.0055
EXPORTS	0.090891	0.027059	3.358970	0.0009
HAY_PRODUCTION	-0.003586	0.010924	-0.328280	0.7429
ENDING_STOCKS	-0.021110	0.003253	-6.488902	0.0000
DAIRY_INVENTORY	0.070289	0.041643	1.687902	0.0922
BEEF_INVENTORY	-0.000895	0.004593	-0.194812	0.8456
STRUCTUAL_DUMMY	0.854683	0.244298	3.498527	0.0005

R-squared	0.765503	Mean dependent var	10.09772
Adjusted R-squared	0.757920	S.D. dependent var	3.929534
S.E. of regression	1.933395	Akaike info criterion	4.189506
Sum squared resid	1502.682	Schwarz criterion	4.325154
Log likelihood	-857.4173	Hannan-Quinn criter.	4.243141
F-statistic	100.9469	Durbin-Watson stat	0.920796
Prob(F-statistic)	0.000000		

FINAL REGRESSION

```
Dependent Variable: ALFALFA_PRICE
Method: Panel Least Squares
Date: 01/31/14   Time: 13:09
Sample: 1 429
Periods included: 32
Cross-sections included: 13
Total panel (balanced) observations: 416
==========================================================================
        Variable           Coefficient   Std. Error   t-Statistic   Prob.
==========================================================================
           C                -5.386236     1.553347    -3.467504    0.0006
   COMMODITY_PRICE           1.056731     0.247956     4.261769    0.0000
     FEEDER_PRICE            0.163979     0.050384     3.254622    0.0012
      MILK_PRICE             0.415176     0.070912     5.854785    0.0000
    MILK_PRICE(-1)           0.314132     0.064801     4.847628    0.0000
         COSTS               0.009053     0.003035     2.982793    0.0030
     PRECIPITATION          -0.126935     0.046257    -2.744087    0.0063
        EXPORTS              0.093246     0.025770     3.618417    0.0003
    ENDING_STOCKS           -0.021541     0.002926    -7.362776    0.0000
   DAIRY_INVENTORY           0.056408     0.028857     1.954758    0.0513
   STRUCTUAL_DUMM
           Y                 0.806096     0.236650     3.406280    0.0007
==========================================================================
R-squared                    0.764912    Mean dependent var       10.09772
Adjusted R-squared           0.759107    S.D. dependent var       3.929534
S.E. of regression           1.928647    Akaike info criterion    4.177601
Sum squared resid            1506.470    Schwarz criterion        4.284182
Log likelihood              -857.9410    Hannan-Quinn criter.     4.219743
F-statistic                  131.7760    Durbin-Watson stat       0.914613
Prob(F-statistic)            0.000000
==========================================================================
```

CHOW-TEST GROUP 1

```
Dependent Variable: ALFALFA_PRICE
Method: Panel Least Squares
Date: 02/15/14   Time: 10:36
Sample: 1 182
Periods included: 13
Cross-sections included: 13
Total panel (balanced) observations: 169
==========================================================================
        Variable          Coefficient    Std. Error    t-Statistic    Prob.
==========================================================================
           C               2.350250      2.236721      1.050757      0.2950
   COMMODITY_PRICE         0.448840      0.324927      1.381355      0.1691
     FEEDER_PRICE          0.214742      0.054316      3.953590      0.0001
      MILK_PRICE           0.380042      0.167487      2.269077      0.0246
    MILK_PRICE(-1)        -0.088842      0.151856     -0.585039      0.5594
        COSTS             -0.010732      0.008650     -1.240728      0.2165
    PRECIPITATION         -0.048292      0.049478     -0.976043      0.3305
       EXPORTS             0.223490      0.157163      1.422033      0.1570
    ENDING_STOCKS         -0.014590      0.003209     -4.546341      0.0000
   DAIRY_INVENTORY         0.075457      0.033228      2.270876      0.0245
==========================================================================
R-squared                  0.357448    Mean dependent var         7.683908
Adjusted R-squared         0.321077    S.D. dependent var         1.443644
S.E. of regression         1.189516    Akaike info criterion      3.242319
Sum squared resid          224.9768    Schwarz criterion          3.427520
Log likelihood            -263.9759    Hannan-Quinn criter.       3.317477
F-statistic                9.827870    Durbin-Watson stat         1.027850
Prob(F-statistic)          0.000000
```

CHOW-TEST GROUP 2

```
Dependent Variable: ALFALFA_PRICE
Method: Panel Least Squares
Date: 02/15/14   Time: 10:39
Sample: 1 247
Periods included: 18
Cross-sections included: 13
Total panel (balanced) observations: 234
========================================================================
      Variable          Coefficient    Std. Error    t-Statistic   Prob.
========================================================================
          C              -5.728052     2.074987     -2.760524     0.0062
   COMMODITY_PRICE        1.244544     0.328610      3.787294     0.0002
     FEEDER_PRICE         0.002981     0.082152      0.036286     0.9711
      MILK_PRICE          0.503868     0.083937      6.002908     0.0000
    MILK_PRICE(-1)        0.414087     0.076744      5.395693     0.0000
        COSTS             0.009324     0.004133      2.256034     0.0250
    PRECIPITATION        -0.136518     0.064929     -2.102569     0.0366
       EXPORTS            0.090265     0.030632      2.946756     0.0036
    ENDING_STOCKS        -0.029834     0.004755     -6.274406     0.0000
   DAIRY_INVENTORY        0.018336     0.040718      0.450328     0.6529
========================================================================
R-squared                 0.766808   Mean dependent var         11.89580
Adjusted R-squared        0.757439   S.D. dependent var         4.283785
S.E. of regression        2.109785   Akaike info criterion      4.372844
Sum squared resid         997.0669   Schwarz criterion          4.520507
Log likelihood           -501.6227   Hannan-Quinn criter.       4.432382
F-statistic               81.84259   Durbin-Watson stat         1.100036
Prob(F-statistic)         0.000000
```