A DECISION MODEL TO DETERMINE CLASS III MILK HEDGING OPPORTUNITIES

by

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ABSTRACT

Fluid raw milk has become one of the largest agricultural commodities, as measured by gross sales, produced in the United States. Since the federal government began to loosen its control over dairy prices in the early 1980's, farm level milk prices have seen dramatic increases in volatility. Further, shrinking profit margins are requiring more and more dairy farmers to carry a significant amount of debt. Because of the greater leverage in the industry and reduced government support, many producers desire to find mechanisms by which to reduce price risk.

Class III milk futures began trading in 1996 with an objective to provide dairy industry players with a means to reduce price risk by transferring that risk to other market players or speculators. Numerous strategies have been proposed for dairy producers to use in price risk reduction that industry participants both support and denounce. One of the objectives of this thesis was to list and analyze a select number of these strategies for their risk-reducing features. Many of these systematic strategies result in lower risk, but the mean Class III price that results from their use was significantly different depending on the strategy used.

Another objective of this thesis was to develop a model-based hedging strategy for Class III milk. Six models were developed to predict the Class III Milk price six months and three months into the future. The results of these models were then compared to the Class III Futures price being offered on the first trading day of the month, six months and three months prior to the production month to be priced. If the futures price was higher, a

hedge was initiated. If the futures price was lower, no hedge was initiated and the cash market was used.

The decision models developed and tested in this thesis not only reduced price volatility, they also increased the mean Class III price obtained as compared to a "cash-only" strategy. While the decision models were successful in-sample, their out-of-sample testing proved to be considerably less successful as all of the model-based strategies underperformed the cash market.

The final area researched by this thesis was that of milk price basis. Basis, as it concerns milk prices, is extremely difficult to predict since it involves both physical milk characteristics and government controlled pricing components. While the predictive models tested gave insight into basis prediction, a clear predictive basis model was not found.

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CHAPTER 1: INTRODUCTION

1.1 Problem

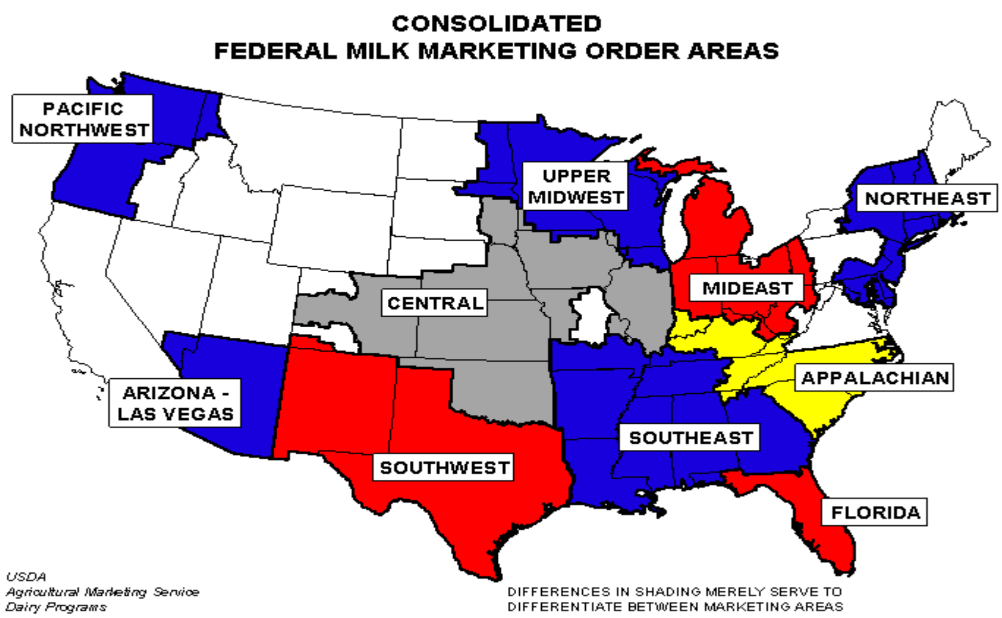
Fluid raw milk ranked as the third largest agricultural commodity, as measured by gross sales, produced in the United States for the period 1996 through 2005, trailing only corn and beef production (United Nations FAO, 2006). Since the federal government began to loosen its control over dairy prices in the early 1980's, farm level milk prices have seen dramatic increases in volatility (Kinser and Cropp, 1998). For producers that are carrying a large debt load or experiencing reduced margins, the reduction of price risk may be a necessity. This thesis will explore some of the systematic milk pricing strategies currently being used by producers and the risk reducing capabilities of those strategies.

Price risk management, through the use of futures and options markets, has been available to many agricultural commodity producers for several years. Grain and livestock producers have seen numerous studies conducted on the positive and negative aspects of hedging price risk. While butter contracts have been sold on commodity exchanges for many years, it has only been since 1993 that cheese and non-fat dry milk contracts have been available, and 1996 that fluid milk contracts have been offered as a tool for dairy farmers to hedge their product's price risk.

Because of the relative newness of dairy related futures contracts, there have been few academic studies completed on different trading strategies to determine whether risk can be successfully managed by using dairy futures contracts. Unlike many other commodities, milk is a "flow commodity," meaning that it is produced and marketed on a daily basis (Manchester and Blayney, 2001). For example, grain is harvested in the fall and can be stored for a period of time while milk is delivered for processing within 48 hours of its daily production. This eliminates storage as a marketing option for milk producers, but consistent monthly hedging can be accomplished since production is delivered and priced during each month.

Because of the complexity of milk prices and the desire of government officials to ensure that fluid milk is available throughout the country, USDA controls the minimum prices that are paid for milk in many regions of the country (figure 1.1). This study

Figure 1.1: USDA Milk Marketing Orders



examines price risk management strategies for producers in the Upper Midwest. Since a vast majority of milk in this region is priced as Class III (milk used in the production of cheese), only Class III price data will be used (prior to 1999, the Class III milk price was referred to as the Basic Formula Price or BFP).

Despite the government's desire to reduce subsidies to the dairy industry, a product support, export enhancement, and deficiency payment program all remain in place to date. Each of these programs helps to keep an artificial floor under the farm-level price of milk.

The government's support program is designed to keep farm-level milk price at or above $9.90 per hundredweight (Manchester and Blayney, 2001). This program is administered by the Commodity Credit Corporation (CCC), a division of USDA's Farm Service Agency. The dairy price support program allows the CCC to purchase cheese, butter, and non-fat dry milk at pre-determined price levels and established product standards. The price for each of these dairy products is established at a level that is intended to support a minimum price for raw milk.

The Dairy Export Incentive Program (DEIP) was implemented during 1985 and has been reauthorized by numerous trade acts several times since its introduction (USDA-FAS, 2006). DEIP enhances domestic milk prices by paying cash bonuses (subsidies) to exporters of certain dairy products. The program is administered by USDA's Foreign Agriculture Service.

Via the 2002 Farm Bill, the federal government also implemented the Milk Income Loss Contract, a deficiency payment that is designed to pay producers for a certain amount of milk when prices fall below a pre-determined level. This program was initially authorized to run from December, 2001 through September, 2005. The Agriculture

Reconciliation Act reauthorized the program through September, 2007 (USDA-FSA, 2006).

In addition to the government-operated price enhancement programs, the dairy industry created its own price enhancement program during 2003. This program was named Cooperatives Working Together and is operated as a division of the National Milk Producers Federation (NMPF, 2003). This program allows producers to voluntarily contribute a portion of their milk revenues to a national pool of money that provides for herd reduction initiatives and an export enhancement program.

Figure 1.2 charts Class III fluid milk prices from January 1988 through June of 2004, while Figure 1.3 demonstrates the increased volatility in monthly Class III fluid milk prices since 1988. While farm-level milk price volatility began to increase with the “whole herd buyout” programs in the mid-1980’s, volatility did not significantly increase until 1996 when the “Freedom to Farm Act” dramatically lowered product support prices to levels where a majority of producers cost-of-production exceeded the support levels. This caused herd contraction and expansion to become much more dramatic, thus leading to more and larger price swings.

Figure 1.2: Monthly Class III/BFP Final Prices

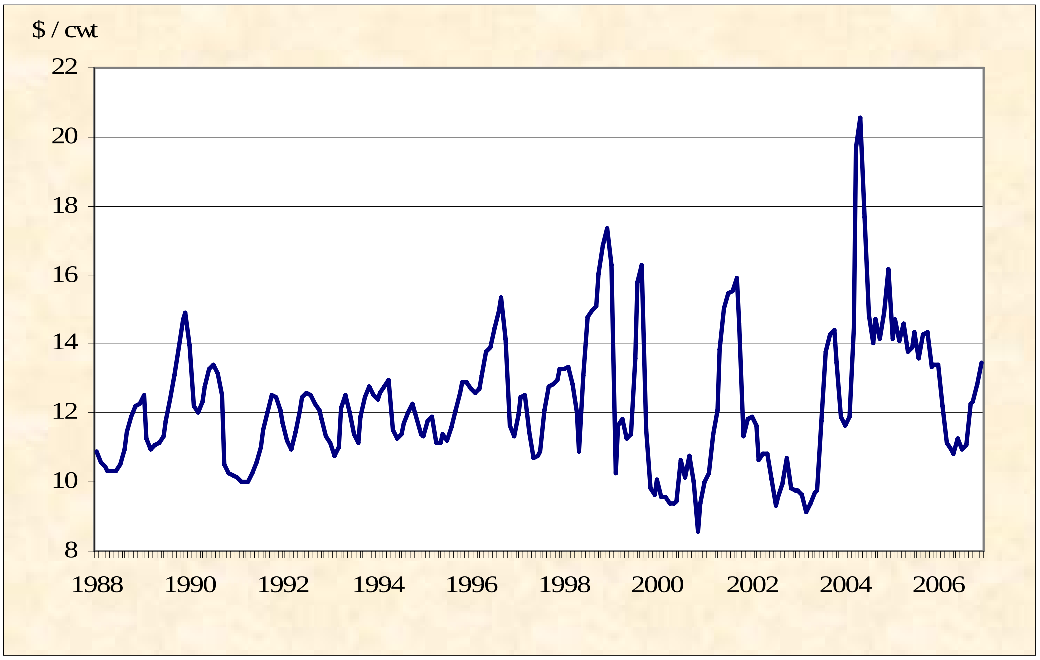
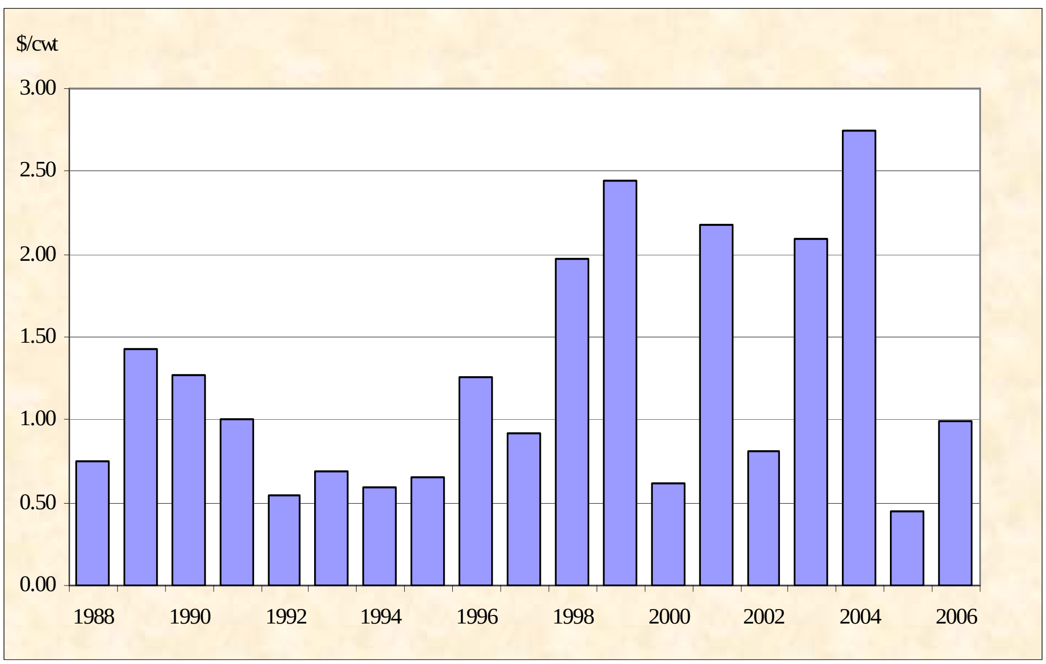


Figure 1.3: Class III/BFP Milk Price Annual Standard Deviation



1.2 Basis

Basis is defined as the difference between the cash price of a commodity and the futures price of the underlying commodity. For milk, basis is calculated as the difference between the monthly gross pay price (mailbox price) and the announced Class III price. Technically, there is no basis in Class III milk prices. Since Class III milk futures are cash-settled to the Class III price announced each month by USDA and this price is universal, the basis would be zero. However, this is only relevant if producers sell only Class III milk. Given that producers market a blend of milk (Class I, II, III, and IV), basis is generally not zero. For the purposes of this study, basis will be defined as the mailbox price (blended milk price) minus the Class III milk settlement price. The settlement price is used as all "pooled" milk in the Upper Midwest Milk Marketing Order is priced to the settlement Class III price announced by USDA.

In most commodities, basis can be described as a function of transportation, interest rates, storage costs, local supply and demand, and aggregate supply and demand. For Class III milk, however, these variables represent a small portion of actual basis. When discussing Class III milk basis, it is important to note that dairy farmers are paid specifically for the amount of butterfat, protein, and other solids that are in their milk. The Class III price takes these three components and standardizes them for the purpose of creating a uniform base price. This means that a producer with milk components higher than the standardized levels (3.5% for butterfat, 3.1% for protein, and 5.9% for other solids) would receive a higher price for their milk. Likewise, a producer would receive a lower price if their components were lower than the standardized level.

There also are additional premiums paid for milk quality, quantity, and other specific attributes (such as a protein premium above and beyond the USDA minimum protein price) that add to basis. These premiums generally are not guaranteed to be paid and are subject to change on a monthly basis unless contractually obligated by the processor to the producer.

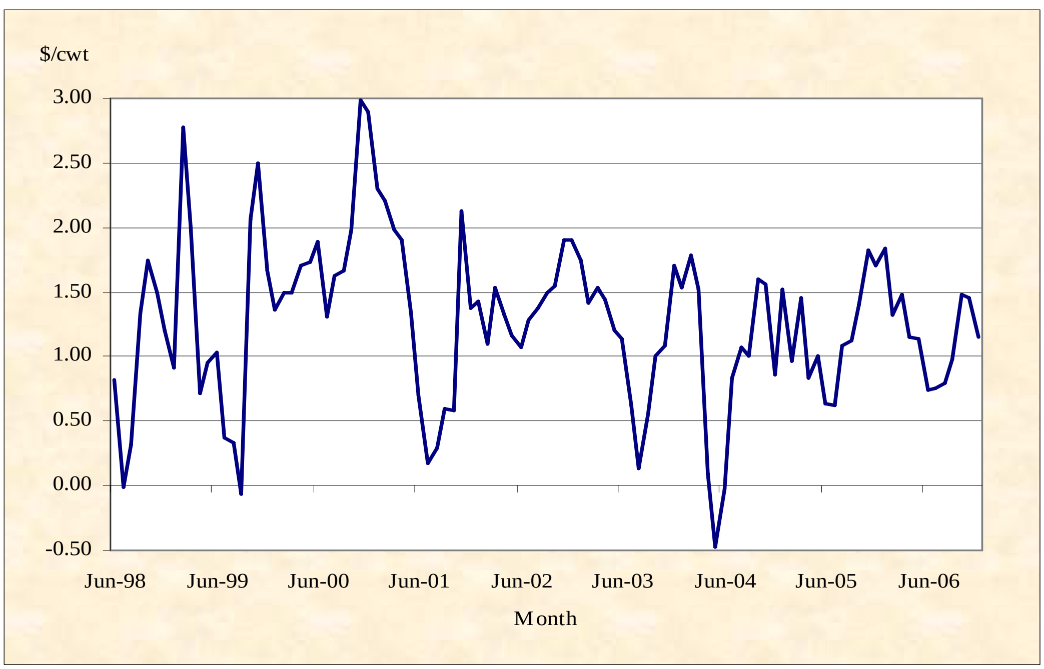
The final component of basis is the “producer price differential” or PPD. The PPD is determined by USDA and is a calculation of all milk pooled in a federal order under the four classes of milk. The prices for the separate classes are determined by the underlying products of each class. Class I represents fluid milk, Class II has mostly soft products, Class III is cheese, and Class IV consists of butter and ice cream. For each class, the volume and product value is calculated so that processors may pay equally for the milk that they are receiving (Jesse and Cropp, 2004).

Generally, the PPD is positive (Class III milk being the base), but when cheese prices rise rapidly, the PPD can turn negative. This occurs because Class I prices, which are announced six weeks prior to the other three classes to allow retailers to know ahead of time what fluid milk will cost, fall below that of the Class III base (Jesse and Cropp, 2004). The PPD is then calculated by taking the total value of the pool of all four classes of milk and comparing that to the value of the Class III milk in the pool. If the total value of the pool is greater than the value of the Class III portion, then the PPD is positive. If the value of the pool is less than that of the Class III portion, then the PPD is negative.

"De-pooling," or opting out of the federal pool system magnifies the monetary effect to the remaining pool participants by forcing them to cover a larger portion of the class shortfall. While all Class I processors must remain in the pools, Class III and IV processors may opt out if they believe that they will not gain anything from remaining in the pool. De-pooling intensifies the negative PPD by requiring the milk remaining in Classes II, III, and IV to pay a higher portion out to the Class I processors. Because there is no limitation on how often processors may get in and out of the pool system, it is very difficult to predict PPD levels.

Figure 1.4 shows milk basis from June, 1997 through December, 2006. Over this period, basis has ranged from -$0.50 to +$3.00 per hundredweight (cwt). The variability in basis was generally greater early in the time period relative to the more recent years.

Figure 1.4: Monthly Historical Milk Basis



1.3 Thesis Objectives

The main objective of this thesis is to determine whether risk can be reduced through the use of model-based hedging in Class III milk futures which relies upon information that is readily available to producers and easy to understand. The client for this thesis will be the dairy farmer. Theoretically, dairy futures can be used to reduce price risk and volatility for both producers and processors; however, this study focuses on strategies that would normally be used by dairy producers to hedge the milk price risk they face in their operations.

Risk, as defined by some producers, is not receiving a milk price that will give them a fair profit. As is normally the case, this definition of risk is rather limited. After experiencing an extended period of prices that are below the cost of production, any price that would achieve a profit may be deemed as "fair." However, "fair" seems to be much higher after producers have enjoyed prices near the upper-end of historical averages. For this study, risk is defined as the measure of volatility (standard deviation) associated with each pricing strategy.

A secondary evaluation will be made to determine the mean price of each strategy. The efficient frontier (Markowitz, 1952) allows for a comparison of risk and reward of each pricing strategy. If two pricing strategies have equal returns, the strategy to choose is the one with the lower expected risk. By analyzing the mean return and standard deviation of each strategy, producers should be able to determine strategies that will best meet their unique situation and goals.

Outside of the main objective of the thesis, there are three sub-objectives for the study. First is to identify the primary hedging strategies that are currently being promoted by industry professionals. Second, an analysis of the historic risk of each of these strategies, as measured by standard deviation associated with the mean price, will be performed to determine the risk reduction that each strategy possesses. The final sub-objective is to develop and test a model designed to predict basis from vantage points of six months and three months prior to the production month.

CHAPTER 2: LITERATURE REVIEW

2.1 General Literature

The literature dealing directly with risk management for marketing milk is somewhat limited due to the relative infancy of specific risk management tools available to dairy producers. Research has been conducted using multiple measures of risk, including but not limited to: standard deviation, value at risk, and conditional value at risk. While all of these studies generally conclude that risk can be reduced by implementing risk management strategies; each calls for further research into appropriate strategic procedures.

There is vast research pertaining to the efficiency of futures markets throughout the world. A considerable portion of this research has centered on the "Efficient Market Hypothesis," (EMH) first popularized by Fama in 1965 and further addressed in his 1970 publication of "Efficient Capital Markets: A Review of the Theory and Empirical Work." Fama concluded that efficient markets fully reflect all information available and that, on average, there is no way to earn excess profits on routine trading strategies.

In further looking at the "Efficient Market Hypothesis," three distinctive forms of EMH are presented. Weak form efficiency, semi-strong form efficiency, and strong form efficiency are all versions of Fama's original research. Grossman and Stiglitz argue in their 1980 article "On the Impossibility of Informationally Efficient Markets" that when information is costly to obtain, those willing to obtain information require a certain profit for obtaining that information. According to this theory, the only market where true strong form of EMH exists is one where information is costless.

2.2 Agriculture Related Literature

All three forms of EMH have been frequently tested in agriculture. Kastens and Schroeder (1995) rejected the null hypothesis of weak-form live cattle futures efficiency. These same researchers looked at semi-strong efficiency in Kansas City wheat futures (1996) and concluded that futures efficiency in this market had improved during the past 50 years and that deferred futures contracts were indeed the best estimate of harvest prices. Zulauf and Irwin (1997) studied market efficiency in crop marketing and concluded that individuals can beat the market, but few can do so consistently. They further stated that this was consistent with Grossman and Stiglitz's model of market efficiency where individuals who consistently earn trading returns have superior access to information and/or superior analytical ability. Dhuyvetter, Dean, and Parcell (2003) found that model-based trading systems using crude oil futures prices to predict diesel fuel prices do have the potential to return positive returns in purchasing diesel fuel. However, the magnitude of these returns was quite small.

Kastens and Dhuyvetter (1999) found mixed results when they applied market-based decision models to Kansas producers of wheat, soybeans, corn, and milo. The decision models for wheat and soybeans did show positive results when comparing the models to cash performance, but the corn and milo models resulted in negative returns. Kastens and Dhuyvetter concluded that systematic hedging models did work on occasion, but positive results were not universal across multiple commodities. They further indicated that models needed to be developed as closely specific to the commodity they were intended to serve in order to reduce model error between different commodities. The researchers did conclude, however, that employing systematic models did reduce price risk across all commodities.

May and Lawrence (2002) concluded that a model needed to use information that was readily available and easily understood if it were going to be useful for producers. Their research centered on the development of a model to reduce the risk associated with profit within the cattle feeding industry. This model was intended to dictate a single risk management decision based upon the probability of a particular return given a normally distributed expected sales price. The model was created to choose between three options: to speculate in the cash market, protect the projected price with a short hedge, or not to participate in the market at all. The decision was based on maximizing return given a certain risk parameter, which was predetermined by the producer. May and Lawrence reported mixed results with this particular model. While there were certain instances where the model was successful, there were others where the model did not predict the correct course of action. Despite the mixed results, the idea of developing a model that is easy to understand and execute, would certainly appeal to dairy producers.

2.3 Dairy Related Literature

Some of the first research into risk management strategies for dairy producers was conducted by Fortenbery, Cropp, and Zapata (1997) at the University of Wisconsin. This research was initiated to determine how milk futures contracts would relate to the actual cash prices for fluid milk. While the relative newness of milk futures limited the significance of the research results, a predictable basis was found to exist in areas where there was heavy product (particularly cheese) production.

Follow-up studies were conducted by Kinser and Cropp in 1998, and Drye and Cropp in 2001. Both of these studies focused on how producers could use Class III milk futures or forward contracts to reduce the risk associated with milk production. The earlier research focused on producers' perceptions of risk management in the dairy industry. Kinser and Cropp concluded that while many producers had the desire to use risk management tools, a large portion lacked the knowledge or understanding of futures and options trading to comfortably use Class III milk futures to hedge their production.

The Drye and Cropp research (2001) focused more on strategy than attitude. Their research was aimed at determining if producers would have been better off using a predetermined risk management strategy than if they had just remained in the cash market. They used basic risk management strategies at 3, 6, or 10 months into the future. The strategies were: straight hedging, purchasing a put option, straight hedging if the futures price was in the top 30 percent of the historical range (defined as the BFP price from January, 1998, through December, 1997), purchasing a put option if the futures price is below the top 50 percent of historical range, straight hedging if the futures price is in the top 50 percent of historical range, purchasing a put if the futures price is in the top 50 percent of historical range, using a "short fence" strategy, and selling a call option.

Drye and Cropp concluded that a significant portion of the strategies tested resulted in a positive change in net income. The strategies that produced a negative return included hedging at six months out if the futures price is in the top 30 percent, hedging at three months if the futures price is in the historical top 50 percent, and selling call options at both three and six months. While not specifically discussed, these results indicate that the Class III futures market at the time of this study may not have been a very efficient market.

In their conclusions, Drye and Cropp state that the focus of price risk management is to guarantee a price that meets or exceeds the goals of the producer. While this may be the primary goal in an ideal world, it could be argued that the purpose of price risk management is to minimize the risk of prices moving in an adverse direction no matter the price level.

A potential weakness of the Drye and Cropp study was the minimal number of years included in the research. The study was conducted using monthly data from 1998 through 2000. Clearly, three years of data make it extremely difficult to develop reliable conclusions. While the small number of years in which milk futures contracts have been traded may limit the reliability of the results of any model, producers need strategies to be identified and tested to determine if they have the opportunity to reduce price risk by using Class III milk futures.

During 2003, there was a pair of papers published on applying Value at Risk in the milk market. The first was done by Zylstra, Kilmer, and Uryasev (2003) at the University of Florida. This study focused on compensating for increased business risk by reducing financial risk. The researchers used the Value at Risk approach since it determines the probability of a certain loss during a given period of time due to adverse market conditions and within a certain confidence level.

The Florida researchers found that when financial risks (debt levels) were increasing, producers could offset that additional risk by reducing business risk through the use of price risk management strategies. Despite the positive results, the methodology used requires producers to determine hedge ratios and risk levels, which may lead to less adoption by producers due to the increased complexity.

This study was followed up by Bamba and Maynard (2004) who applied the Value at Risk methodology to milk price risk management in four separate regions of the country. Value at Risk is a calculation used to measure the potential change in the value of an asset of a specific period of time and under normal circumstances. Bamba and Maynard desired to use a measure of Value at Risk; combined with the appropriate hedge ratios using the "generalized conditional hedge ratio technique," developed by Myers and Thompson (1989). The study also incorporated uniform trigger points of $11 and $12 per hundredweight so that hedges could only be placed if prices were above these respective points.

Bamba and Maynard concluded that hedging in regions where Class III milk usage was high was more effective than in locations where Class III usage was lower. This was, for the most part, due to more accurate basis prediction. They also concluded that the use of Value at Risk methodology at the 90 and 95 percent confidence levels reduced the variation in mailbox prices (the actual price that producers receive). Using confidence levels higher than the 95^{th} percentile tended to cause no action to be recommended by the model.

Despite the positive results found in both the Value at Risk studies, these strategies do not have the qualities that May and Lawrence championed. Value at Risk is a relatively new concept that has little understanding within the dairy industry, which violates the "easy-to-understand" requirement. Furthermore, by requiring producers to quantify a level of risk that they are comfortable with, this model also violates the "easy information" requirement.

Regardless of the methodology used, any research into the effectiveness of milk price risk management is going to be limited by the relatively small amount of information available. However, studies that can rely upon additional data and possibly the use of out-of-sample analyses need to be conducted in order to validate much of the literature available that specifically pertains to Class III milk futures.

CHAPTER 3: THEORY AND METHODOLOGY

3.1 Hedging Theory

While many theories on commodity hedging have been produced for review over the years, this section will focus on those that are paramount to developing models for the infant dairy price risk management arena.

The first, and most significant, theory that will be incorporated into this study is that of efficient markets (Fama, 1965). The basis of this theory is that an efficient market will incorporate all available information into its price, thus leaving no room for additional profit. Subsequent price movement is thus due to new information being incorporated into the marketplace. Since Class III fluid milk futures are traded on the Chicago Mercantile Exchange and have reached a sustainable volume, it should be concluded that the market is genuine and is subject to the same rules of efficiency as other commodity markets.

The efficient market theory has subsequently been divided into three forms; weak, semi-strong, and strong. Since the dairy market consists of numerous farmers supplying a limited number of processors, it stands to reason that information would not be equally distributed amongst the participants. This would mean that if information and the quality of that information had varying costs, those that were willing to commit the capital to collect and analyze information would expect a commensurate return for their investment (Grossman and Stiglitz, 1980).

Since it is likely that information in the dairy market is both variable in cost and quantity, it stands to reason that the success of a model-based hedging strategy in consistently reducing price volatility is a function of the cost that the participants are willing to pay to gather the information to be used in the model. For a model to be actively incorporated by dairy producers, the model must employ information that is readily accessible and the model must be easily understood by those using it (May and Lawrence, 2002).

Under traditional economic rule, supply and demand work in cooperation to ultimately determine price. The dairy market is one where everyone is aware of the supply factors (due to publication by USDA agencies). The demand factors are more obscure since there are a limited number of purchasers of raw fluid milk. In order to satisfy the ideal of "readily available information," only USDA reported factors will be used in determining the model. Ideally, both supply and demand variables would be used in the model equation. Factors that will be used in this model will include the year-over-year change in dairy herd numbers, cheddar cheese production figures, production expense ratios, and cheese cold storage figures.

In order to determine whether or not the decision model is effective, the ultimate cash price needs to be compared with the predicted price (May and Lawrence, 2002). The results of the decision model will also be tested for their volatility (measured by standard deviation) in comparison to cash prices. Coefficient of variation will be used to help judge the combination of risk and return versus the cash market.

This study will attempt to determine if milk basis can be accurately predicted and if it should be incorporated into the determination of the hedging model's success. Milk basis is variable by both time of year (Drye and Cropp, 2001) and the degree by which Class III prices have moved during the previous two production months (Bamba and Maynard, 2004). Basis is further affected by variations in the four classes of milk use, also referred to as the "producer price differential." The distribution of use between these classes is the foundation for revenue re-distribution between processors, thus equalizing the local differences in raw milk price. Because not all processors are required to participate in all "pools" the predictive ability of this portion of milk basis is greatly diminished.

3.2 Methodology

Statistical data for this study will be collected from USDA's National Agricultural Statistics Service (NASS) and Economic Research Service (ERS). Class III price data will be collected from the Chicago Mercantile Exchange (CME). Class III milk futures began trading during 1996 at the New York Mercantile Exchange, but did not begin at the CME until mid-1997. In order to get complete data for individual trading months, this study will use data beginning in June of 1998 through June of 2004. The NASS and ERS data will also incorporate these time frames in order to keep the data uniform.

For the purposes of this study, the Class III futures prices that will be used are the daily settlement price for the first business day of the month. There is no specific reason for picking this date except for the simplicity of choosing a date that is not subject to change if falling on a holiday or non-trading day.

3.2.1 Known Hedging Strategies

The strategies to be tested are those found to be prevalent in academic literature on Class III milk price protection. The majority of the strategies are time or price triggered. All of the strategies were tested at both three and six months prior to the production month. For example, if the production month was June of 1998, the three month hedge date would be April 1, 1998 while the six-month hedge date would be January 2, 1998. The three and six month trigger points were selected due to their use in previous research. While current Class III futures data indicate pricing decisions could be made up to two years in advance, this was not the case during the 1998 though 2004 years where frequently very little trading volume took place before six months prior to the contract month.

Each of the strategies will be tested for its relationship to the default strategy of not hedging at all and taking the announced cash price during each month. Statistics to be gathered will include: mean, standard deviation, maximum price, minimum price, median price, range, percentage of months where a hedge was placed, percentage of positive hedges, percentage cash or positive hedge, and percentage success. Because of the perception by many dairy farmers that not hedging would be preferred over a negative value hedge (i.e., a hedge that results in a loss on the futures position), the percentage of cash plus positive trades will be calculated. While this statistic has very little meaning in reality, it has been calculated for a reference point. Percentage success is defined as the best possible choice given perfect hind-sight. For example, if the decision was to hedge, was the hedge minus costs better than cash? If the decision was cash, was that better than a hedge minus costs?

3.2.2 Class III Hedging Model

The Class III hedging model is based upon the likelihood that production response will be either higher or lower given the supply indicators that producers have available three and six months prior to the production month. The demand indicators that are being used for this study are 20-state dairy herd, milk-to-feed price ratio, cheddar cheese production, and American cheese in cold storage. Each of these figures is reported monthly by NASS and is easily obtainable by producers via NASS's public website. In order to capture the general trend of change in each of these factors and to eliminate seasonal fluctuations, the econometric models will use year-over-year percentage change in each factor in place of the actual reported figures.

Dummy variables will be included in the model so that seasonal supply and demand trends can be accounted for. The dummy variables will give a value to the month of production, on a quarterly basis. The quarters were determined by looking at seasonal differences in production and comparing that to the mean Class III price of each month from 1998 through 2004. Quarter 1 was determined to be February, March, and April; quarter 2 consists of May, June, and July; quarter 3 is August, September, and October; and quarter 4 is November, December, and January. Due to regional production differences, these quarters may not represent the "best fit" for marketing orders other than the Upper Midwest. Quarterly dummy variables were chosen over monthly dummy variables in an effort to limit the number of variables in the models.

Regression analysis will be used to determine the ultimate model equations. Herd change, cheddar cheese production change, and milk-to-feed ratio change are used in each of the regressions. Change in American cheese in cold storage is added to the second regression, and seasonal dummy variables will be added to the third regression for each the three- and six-month time-frames.

Upon creation of the equation used to predict the Class III milk price at the three-month and six-month periods, a decision to hedge or not to hedge is made. The decision rule is the following: if the futures price on the first business day of the month, three months prior to the production month, is higher than the predicted price, a hedge is initiated. If the futures price is equal to or less than the predicted price, the production will be marketed using the cash market. The same process is used at the six-month period.

3.2.3 Class III Basis Model

The starting point for developing the Class III basis model will be the model developed by Bamba and Maynard (2004). This model took into account seasonal variations, historic basis figures, and the expected future Class III price to predict future basis levels. Additional variables will also be evaluated for their predictive ability. The variables will include the futures prices one month prior and two months prior to the production month. For example, if the production month is June of 1998, the futures prices for May and April of 1998 will be used to help predict basis. This is done in an attempt to capture rapid changes in the price of milk coming into the production month.

Further tests were conducted on a naïve basis to determine if the trailing 12-month, 6-month, or 3-month simple averages would accurately predict basis. A test will also be performed on the average basis of the production month for the previous three years.

All of the models and strategies will be tested for the statistical difference from the actual basis. The primary statistical factors used to determine suitability are mean absolute error and the range of the errors.

CHAPTER 4: SYSTEMATIC HEDGING STRATEGY EVALUATION

4.1 Systematic Strategy Descriptions

Five unique strategies were evaluated for this paper (Table 4.1) hedging every production month at a specified date, hedging if the futures price is greater than $12, hedging if the futures price is greater than the historic average price for the production month, hedging if the futures price is greater than the historic 67th percentile price for the production month, and hedging if the futures price is greater than the historic 84th percentile price for the production month. Each of the strategies was evaluated at both the six-month and three-month time points which, with the control strategy (only using the cash market), brings the total number of evaluations to eleven. In order to take into account hedging costs (commissions, interest, and other costs), $0.10 per hundredweight (cwt) has been deducted from the Class III price in every month where a hedge is placed. While this cost may be higher than many producers could obtain if hedging on their own, it is consistent with what Land 'O Lakes, Alto Dairy, and Mullen's Cheese were charging when contacted in 2004.

The price points that were used in the Class III hedging strategies were calculated using historical prices from January 1996 through June 2004, as reported by USDA. January 1996 was chosen as the start-date for the Class III price statistics since this was the year that a noticeable increase in milk price volatility was observed. The average monthly price used is the mean of each month's reported Class III price range. This same range was used to determine the 67th and 84th percentile prices used in the strategies. Table 4.2 lists the statistical differences between the various hedging strategies evaluated.

The control strategy is simply taking the USDA announced cash price and is referred to as the "cash" strategy. The mean price of the cash strategy is $12.18, with a range of $12.01 based upon a high price of $20.58 and a minimum price of $8.57. The standard deviation of cash is $2.77 while the median price is $11.42.

Table 4.1: Class III Systematic Hedging Strategy Definitions

Code	Strategy	Definition
A	***Cash***	Use the announced Class III price each month.
B	***t - 3 mo***	Hedge Class III price using futures on 1st business day, three months prior to delivery month. Hedge is executed every month.
C	***3mo > 12***	Hedge Class III price on 1st business day, three months prior to delivery month ONLY if futures price is above $12 for delivery month.
D	***3mo > ave***	Hedge Class III price on 1st business day, three months prior to delivery month ONLY if futures price is above the average for delivery month.
E	***3mo > 67%***	Hedge Class III price on 1st business day, three months prior to delivery month ONLY if futures price is in the top 67% of historic prices for delivery month.
F	***3mo >84%***	Hedge Class III price on 1st business day, three months prior to delivery month ONLY if futures price is in the top 16% of historic prices for delivery month.
J	***t - 6 mo***	Hedge Class III price using futures on 1st business day, six months prior to delivery month.
K	***6mo > 12***	Hedge Class III price on 1st business day, six months prior to delivery month ONLY if futures price is above $12 for delivery month.
L	***6mo > ave***	Hedge Class III price on 1st business day, six months prior to delivery month ONLY if futures price is above the average for delivery month.
M	***6mo > 67%***	Hedge Class III price on 1st business day, six months prior to delivery month ONLY if futures price is in the top 67% of historic prices for delivery month.
N	***6mo >84%***	Hedge Class III price on 1st business day, six months prior to delivery month ONLY if futures price is in the top 16% of historic prices for delivery month.

Table 4.2: In-Sample Class III Systematic Hedging Strategy Statistics

Code	Strategy	Mean	Std Dev	CV	Min	Max	Range	Median
A	***Cash***	12.18	2.77	0.23	8.57	20.58	12.01	11.42
B	***t-3mo***	11.91	1.22	0.10	9.69	15.40	5.71	11.71
C	***3mo>$12***	12.06	1.95	0.16	8.57	19.66	11.09	12.14
D	***3mo>ave***	12.06	2.14	0.18	8.57	19.66	11.09	11.89
E	***3mo>67%***	12.07	2.32	0.19	8.57	19.66	11.09	11.78
F	***3mo>84%***	12.35	2.78	0.22	8.57	20.58	12.01	11.63
J	***t-6mo***	11.95	0.73	0.06	9.75	13.25	3.50	11.95
K	***6mo>$12***	12.31	2.06	0.17	8.57	20.58	12.01	12.35
L	***6mo>ave***	12.47	2.34	0.19	9.11	20.58	11.47	12.10
M	***6mo>67%***	12.26	2.51	0.20	8.57	20.58	12.01	11.87
N	***6mo>84%***	12.22	2.76	0.23	8.57	20.58	12.01	11.49

t-3mo represents the strategy hedging production on the first business day, three months prior to the production month, every month. This strategy resulted in a mean price of $11.91 with a range of $5.71 resulting from a maximum price of $15.40 and a minimum price of $9.69. The standard deviation of *t-3mo* is $1.22, resulting in a coefficient of variation (CV) of 0.10.

3mo>$12 represents the strategy of hedging three months prior to the production month only if that price is greater than $12. This strategy results in a mean price of $12.06 with a range of $11.09. The minimum price was $8.57 and the high price was $19.66. The standard deviation of *3mo>$12* is 1.95 with a CV of 0.16.

The next strategy that is executed three months prior to the production month is *3mo>ave*. This strategy calls for a hedge to be initiated if the Class III futures price on the first business day of the month three months prior to the production month is greater than the historical average price for that month. This strategy resulted in mean price of $12.06

with a range of $11.09 ($19.66 max, $8.57 min) and a median price of $11.89. The standard deviation of *3mo>ave* was 2.14 with a CV of 0.18.

3mo>67% represents the strategy where a hedge is initiated on the first business day, three months prior to the production month only if the futures price is greater than the 67th percentile price for that month. This strategy resulted in a mean price of $12.07 with a range of $11.09 (max $19.66, min $8.57) and a median price of $11.78. The standard deviation of *3mo>67%* was 2.32 with a CV of 0.19.

The final strategy tested at the three-month interval is *3mo>84%*. This strategy is similar to the previous ones except for the trigger price being moved up to greater than the 84th percentile of the range. This strategy resulted in a mean price of $12.35 with a range of $12.01 (max $20.58, min $8.57) and a median price of $11.63. The standard deviation was 2.78 with a CV of 0.23.

The six-month strategies begin with *t-6mo* which is a strategy where a hedge is initiated on the first business day, six months prior to the production month. A hedge is placed each month. This strategy resulted in a mean price of $11.95 with a range of $3.50. The maximum price received was $13.25 while the minimum was $9.75 and median price was $11.95. This strategy resulted in the lowest standard deviation of all strategies tested at 0.73 and a CV of 0.06.

6mo>$12 is a strategy where a hedge is initiated on the first business day, six months prior to the production month only if the futures price is greater than $12. This strategy resulted in a mean price of $12.31 and a range of $12.01. The standard deviation was 2.06 with a CV of 0.17.

6mo>ave is basically the same strategy as the previous with the exception of the trigger point moving from $12 to the monthly average price. This strategy resulted in a mean price of $12.47, a range of $11.47 (max $20.58, min $9.11) and a median price of $12.10. The standard deviation of *6mo>ave* was 2.34 with a CV equaling 0.19.

The next six-month hedging strategy evaluated was *6mo>67%*. This hedge is initiated on the first business day of the month, six months prior to the production month only if the futures price is greater than the 67th percentile of that individual month's given range of prices. This strategy resulted in a mean price of $12.26 with a range of $12.01 and a median price of $11.87. The standard deviation was 2.51 with a CV of 0.21

The final six-month strategy is *6mo>84%*. This strategy is basically the same as the previous, except that the hedge rule is moved from the 67th percentile to the 84th percentile. The mean price of this strategy was $12.22 with a range of $12.01 (max $20.58, min $8.57) and a median price of $11.49. The standard deviation is 2.76 with a CV of 0.23.

4.2 Systematic Strategy Analysis

There are many methods by which hedging strategies can be analyzed to determine which should be used. All of these decision making tools use the statistics of each strategy, combined with the individual decision makers risk preferences to make a final determination. The following decision making tools were used to analyze the Class III systematic hedging strategies defined in Chapter 4.1: highest expected value, expected standard deviation, efficient frontier, coefficient of variation, percentage of positive trades, percentage of positive trades plus cash trades, and the percentage of "best choice" trades (percentage success).

The highest expected value is simply the largest mean Class III price. Table 4.3 shows the differences between the varying strategies and certain decision-making criteria. The table is sorted top to bottom by ascending order of coefficient of variation. The highest mean price was garnered by the *6mo>ave* strategy at $12.47. The lowest mean Class III price was $11.91 using the *t-3mo* strategy. These mean prices are compared to the control (*Cash*) strategy's mean price of $12.18.

Table 4.3: In-Sample Class III Systematic Hedging Strategy Analysis

Code	Strategy	Mean	Std Dev	CV	% Trade[1]	% + Trade[2]	% Cash or +[3]	% Success[4]
J	***t - 6 mo***	11.95	0.73	0.061	100.0%	58.9%	58.9%	58.9%
B	***t - 3 mo***	11.91	1.22	0.103	100.0%	57.5%	57.5%	53.4%
C	***3mo > 12***	12.06	1.95	0.161	43.8%	50.0%	78.1%	46.6%
K	***6mo > 12***	12.31	2.06	0.167	52.1%	65.8%	82.2%	57.5%
D	***3mo > ave***	12.06	2.14	0.178	35.6%	53.8%	83.6%	46.6%
L	***6mo > ave***	12.47	2.34	0.187	37.0%	77.8%	91.8%	58.9%
E	***3mo > 67%***	12.07	2.32	0.192	20.5%	53.3%	90.4%	45.2%
M	***6mo > 67%***	12.26	2.51	0.205	17.8%	76.9%	95.9%	47.9%
F	***3mo >84%***	12.35	2.78	0.225	5.5%	100.0%	100.0%	52.1%
N	***6mo >84%***	12.22	2.76	0.225	1.4%	100.0%	100.0%	42.5%
A	***Cash***	12.18	2.77	0.228	0.0%	0.0%	100.0%	100.0%

1 months of initiated trades/total months
2 months of initiated positive trades/total months
3 (months of initiated positive trades plus no trades)/total months
4 number of "best choice" months/total months

The highest standard deviation was the *3mo>84%* strategy at 2.78, compared to only using the cash market where standard deviation of Class III price came in at 2.77. The lowest standard deviation was 0.73, attained by implementing the *t-6mo* strategy. This strategy significantly reduced the volatility of Class III prices from that of the *Cash* strategy. The *t-3mo* strategy also reduced standard deviation in comparison to *Cash* by more than half, coming in at 1.22.

The coefficient of variation (CV) uses both mean return and standard deviation to give decision makers a single number by which to choose a hedging strategy. CV is simply the standard deviation divided by the mean return or in this case, the mean price. This tool allows the decision maker to rank differing means and standard deviations (as long as they represent the same variables) by their return versus risk. The lowest CV of the systematic hedging strategies (the best choice) was *t-6mo* at 0.06 followed by *t-3mo* at 0.10. The highest CV's came in at 0.23 for the *Cash, 3mo>84%,* and *6mo>84%* strategies. It should be noted that the two lowest CV strategies (theoretically the top two choices) also had the lowest mean returns. This may not be a satisfactory result for a producer willing to take on a higher level of risk.

The percentage of positive hedges (% + Trade) is defined as the number of positive monthly hedges divided by the total number of months hedged. While this statistic may not seem important, many producers gauge the success of their risk management program by how many times they make money on the hedge as compared to losing money. There were two strategies that resulted in 100 percent of trades being positive (*3mo>84%* and *6mo>84%*), however, of the 73 months tested, these strategies were only implemented during four and one months, respectively. Of months that traded at least 15 percent of the time, the top percentage of positive hedges was *6mo>ave* and *6mo>67%* at 77.8 and 76.9

percent, respectively. The lowest percentage of positive hedges was the *3mo>12* strategy at 50.0 percent.

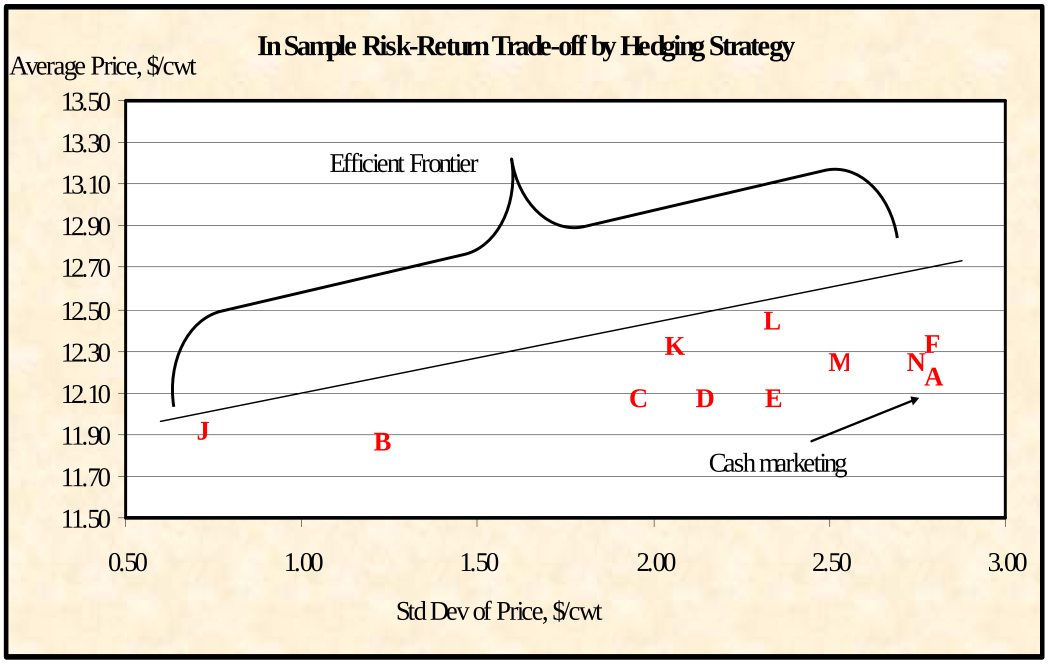
Producers may also rule a strategy as successful by a low percentage of hedges that resulted in a negative return from the hedge transaction. In other words, it is acceptable to lose money if the chosen strategy was cash but it is unacceptable to lose money in a hedge position. From a positive perspective, this is the equivalent of the sum of positive hedges and cash marketings (% *Cash* plus % positive trade). Again, there are strategies that scored 100 percent in this tool, but were extremely low on the number of months that hedges were initiated. When only considering strategies that were initiated more than 15 percent of the time, *3mo>67%* came in cash or positive 95.9 percent of the months considered. *6mo>ave* also scored very well in this category with 91.8 percent of months being cash or positive. At the low end were the *t-3mo* and *t-6mo* strategies at 57.5 and 58.9 percent respectively.

Another measure would be to look back in hindsight to determine if the ultimate decision was the best possible choice. This calculation is determined by comparing the cash price to the hedging opportunities afforded at the six-month and three-month intervals and considering hedging costs for the months where hedges were initiated. For the purposes of this study, hedging costs were considered to be $0.10 per cwt. Since there is a cost to implementing the hedge, it is possible to have a situation were a hedge resulted in a gain but the cost of the hedge resulted in a price less than what would have been received if no hedge were implemented. Under this scenario, the best choice (outside of the cash market) would have been *t-6mo* and *6mo>ave* at a success rate of 58.9 percent. The least successful strategy was *6mo>84%*, coming in at 42.5 percent.

The final decision making tool considered is the efficient frontier. This tool plots the mean price and standard deviation in order to compare risk and return. The efficient frontier rule suggests that if two strategies have equal returns, the strategy with the lower risk (standard deviation) will be chosen. Unfortunately, this decision tool does not incorporate the risk tolerances of the individual producer; it only shows which strategies are the best on a specific frontier.

Figure 4.1 plots the systematic strategies that have been discussed in this chapter. The alphabetic plot labels are defined in Table 4.1 and identified in Table 4.3. Points J, K, and L appear to be on the efficient frontier, while point C would be considered acceptable for those wishing to reduce their risk level from strategies K and L. In this case, point J represents *t-6mo,* point K represents *6mo>$12*, point L represents *6mo>ave*, and point C represents *3mo>$12*. Point B represents *t-3mo* and would be eliminated since point J has a higher mean return and less risk. For the same reasons, all other strategies would also be eliminated from consideration since another strategy with an equal or higher return could be used with less risk.

Figure 4.1: Systematic Strategy Efficient Frontier



4.3 Class III Systematic Hedging Strategy Summary

The efficient frontier represented by the nonparametric line drawn into Figure 4.1 demonstrates that a majority of the systematic Class III hedging strategies can be eliminated since there are other strategies that provide for equal or greater return with less risk.

Of the strategies tested, it would appear that the *Cash* (A) strategy would be one of the less desirable strategies since it plots with the poorest risk-return position. The *Cash* strategy ranks at the bottom for coefficient of variation and is the second-poorest strategy when considering standard deviation. The *Cash* strategy does rank in the middle for mean return ($2.18) with five strategies higher and five below.

For the most risk-adverse producers, the strategy *t-6mo* (J) provides the greatest risk reduction. This strategy is executed for every production month by hedging the Class III price six-months prior to the production month. While the strategy returned a mean price 23 cents less than the *Cash* strategy, it reduced price volatility from the *Cash* standard deviation of 2.77, to a much less volatile 0.73. The *t-6mo* also has the lowest coefficient of deviation at just 0.06.

Both *3mo>$12* (C) and *6mo>$12* (K) have higher mean returns than *t-6mo* at $12.06 and $12.31, respectively. As expected, with the higher returns, these two strategies have higher standard deviations of 1.95 and 2.06, respectively. Another factor that could be used when choosing between these two strategies is percentage success. While *3mo>$12* has a slightly lower standard deviation than the six-month variety, *6mo>$12* has a considerably higher success percentage at 57.5 percent versus 46.6 percent.

The fourth strategy that is acceptable for use is *6mo>ave* (L). This strategy has the highest mean price of the eleven systematic strategies tested at $12.47. As compared to the control strategy (*Cash*), *6mo>ave* has a mean price that is 29 cents higher and a standard deviation of 2.34 which is 0.43 lower than the control. This strategy also has the highest success rate (tied with *t-6mo*) at 58.9 percent.

Clearly, the use of a systematic hedging strategy will either reduce the volatility in Class III prices, or increase the mean Class III price at a similar or lower risk level. While all of the strategies could be used, the efficient frontier clearly eliminates many of the systematic strategies evaluated. Continued testing will further validate and eliminate systematic strategies as they are presented.

4.4 Out-of-Sample Testing Summary

To test the conclusions offered in the previous section, all of the systematic hedging strategies were tested out-of-sample. This period ranged from July 2004 through December 2006. While all four of the systematic hedging strategies that were considered successful in the in-sample test continued to reduce risk over *Cash* out-of-sample, *Cash* improved markedly and was considered a viable strategy out-of-sample as measured in the efficient frontier (Figure 4.2).

Table 4.4 lists selected measures from the out-of-sample data. The *Cash* strategy had the second highest mean price of $13.33 (equal to *3mo>84%* at $13.33 and behind *6mo>84%* at $13.36) and had a standard deviation of 1.44, considerably less than the 2.77 standard deviation observed in the in-sample data. The top strategy out-of-sample for coefficient of variation was strategy K, *6mo>$12* with a CV of 0.07.

Strategy K, *6mo>$12*, had the lowest standard deviation of the out-of-sample tests at 0.94, while having a mean return only 16 cents less than *Cash*. It should be noted that this strategy also reduced risk in the in-sample testing and also resulted in a mean price of $12.31, 13 cents higher than the in-sample *Cash* price. While the risk of the *6mo>$12* strategy is considerably higher than the *t-6mo* strategy, its relative success in both tests periods warrants its consideration as a long-term hedging solution. Likewise, the *6mo>ave* strategy also performed well in both tests, beating *Cash* in both tests for standard deviation and coefficient of variation. This strategy also bested the mean *Cash* price by 29 cents in-sample while giving up 30 cents out-of-sample.

Figure 4.2: Systematic Strategy Efficient Frontier

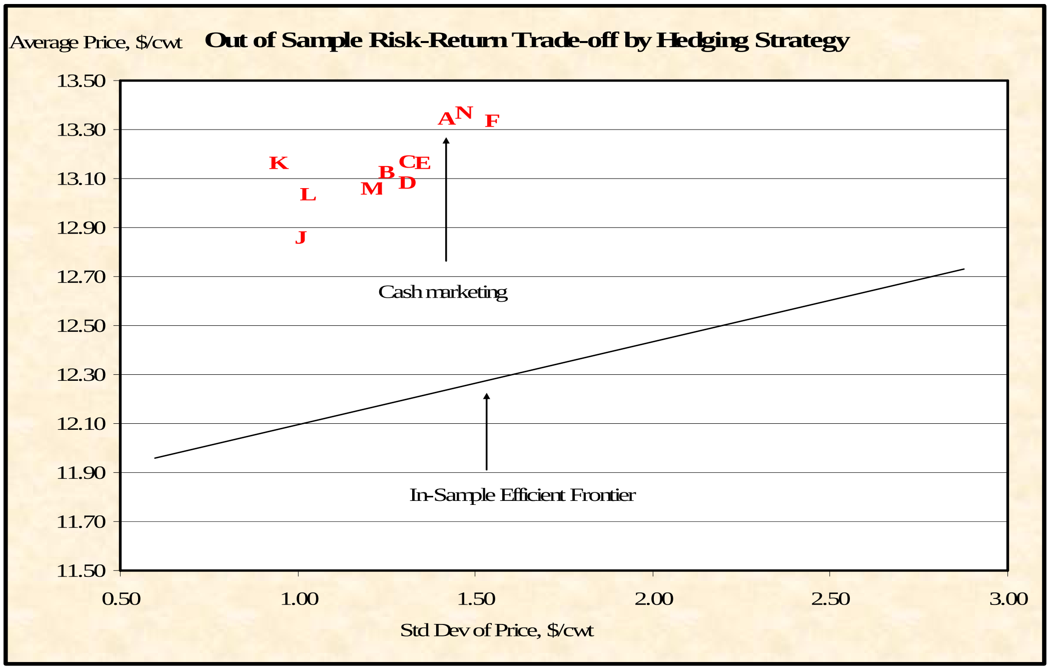


Table 4.4: Out-of-Sample Class III Systematic Hedging Strategy Analysis

Code	Strategy	Mean	Std Dev	CV	% Trade[1]	% + Trade[2]	% Cash or +[3]	% Success[4]
K	***6mo > 12***	13.17	0.94	0.071	80.0%	54.2%	63.3%	60.0%
L	***6mo > ave***	13.03	1.02	0.079	80.0%	50.0%	60.0%	53.3%
J	***t - 6 mo***	12.85	1.02	0.079	100.0%	40.0%	40.0%	40.0%
M	***6mo > 67%***	13.07	1.21	0.093	40.0%	41.7%	76.7%	46.7%
B	***t - 3 mo***	13.10	1.27	0.097	100.0%	46.7%	46.7%	40.0%
C	***3mo > 12***	13.16	1.29	0.098	86.7%	46.2%	53.3%	40.0%
D	***3mo > ave***	13.09	1.29	0.098	83.3%	44.0%	53.3%	36.7%
E	***3mo > 67%***	13.15	1.35	0.102	60.0%	44.4%	66.7%	40.0%
A	***Cash***	13.33	1.44	0.108	0.0%	0.0%	100.0%	100.0%
N	***6mo >84%***	13.36	1.46	0.109	16.7%	60.0%	93.3%	56.7%
F	***3mo >84%***	13.33	1.55	0.116	30.0%	55.6%	86.7%	50.0%

1 months of initiated trades/total months
2 months of initiated positive trades/total months
3 (months of initiated positive trades plus no trades)/total months
4 number of "best choice" months/total months

CHAPTER 5: MODEL-BASED CLASS III HEDGING STRATEGY

5.1 Class III Model Development

One of the sub-objectives of this thesis was to develop and test a Class III price prediction model based upon information that is readily available to producers and easy to understand The model could then be used by the producer to determine if the Class III futures market provides them an opportunity to hedge their milk at a price higher than the model predicts. In order to accomplish this objective, a thorough review of available data was conducted. In the end, four specific data sets were chosen to evaluate as independent variables: 20-State Dairy Herd, Milk-to-Feed Ratio, Cheddar Cheese Production, and American Cheese Cold Storage Stocks. Table 5.1 defines the different variables used in the model development and their abbreviations.

Table 5.1: Class III Hedging Model Variable Definitions

Variable	Definition
CIII	Actual Class III price for production month
T	Projected production month
t-3	Class III price of projected month on first business day, 3 months prior to delivery
t-6	Class III price of projected month on first business day, 6 months prior to delivery
S1	Seasonal dummy variable for Feb - Mar - Apr production month
S2	Seasonal dummy variable for May - Jun - Jul production month
S3	Seasonal dummy variable for Aug - Sep - Oct production month
S4	Seasonal dummy variable for Nov - Dec - Jan production month
Cy-6	YOY % change in cheddar production, lagged 6 months from production month
Cy-9	YOY % change in cheddar production, lagged 9 months from production month
Mfy-4	YOY % change in Milk-to-Feed Ratio, lagged 4 months from production month
Mfy-7	YOY % change in Milk-to-Feed Ratio, lagged 7 months from production month
Hy-5	YOY % change in 20-State Dairy Herd, lagged 5 months from production month
Hy-8	YOY % change in 20-State Dairy Herd, lagged 8 months from production month
ACSy-5	YOY % change in American Type Cold Storage, lagged 5 months from production month
ACSy-8	YOY % change in American Type Cold Storage, lagged 8 months from production month

Each of these statistics was chosen because of its ease of understanding, and its relationship to the supply and demand function of milk price. The 20-state dairy herd was chosen to represent changes in the supply of milk. The use of the milk-to-feed ratio was intended to capture changes in the cost of producing milk in relationship to price. It is a measure of profitability. Since Class III milk price has a direct relationship with the price of Cheddar cheese, the data for the production of this product are relevant. Finally, the variable American cheese cold storage stocks was chosen to help represent the demand side of the equation. Theoretically, if stocks of cheese are increasing, demand for raw milk will decrease, while if they are decreasing, demand for raw milk will increase.

Each of the four factors used in the development of the Class III prediction model will be converted to year-over-year (YOY) percentage change. This is being done in order to capture the long-term changes in the independent variables and to eliminate short-term, month-to-month changes that may skew the prediction of the dependent variable, Class III price.

Figures 5.1 though 5.4 graphically illustrate the year-over-year changes in the independent variables used in the regression analysis. Figure 5.1 gives a very clear view of the cyclical nature of milking herd in the 20 largest producing states. This chart also shows a clear divergence during the out-of-sample period, especially during 2006 where year-over-year change in milking herd inventories was higher than seen at any point in the study period.

Figure 5.2 shows year-over-year change in cheddar cheese production. This data series is more volatile than herd numbers but does show some of the same cyclical tendencies. Interestingly, while herd growth was high during 2006, cheddar production growth was much less pronounced. This could represent a change in the supply/demand equation for cheddar cheese.

Figure 5.3 represents year-over-year change in the milk-to-feed ratio. This data series also shows a pronounced cyclical trend, which is very closely inverted to the dairy herd data series. Figure 5.4 represents year-over-year changes in American cheese stocks in cold storage. This data series historically has been very volatile, but the chart of the data clearly shows a reduction on that volatility over the past few years.

Figure 5.1: 20-State Dairy Herd YOY Change

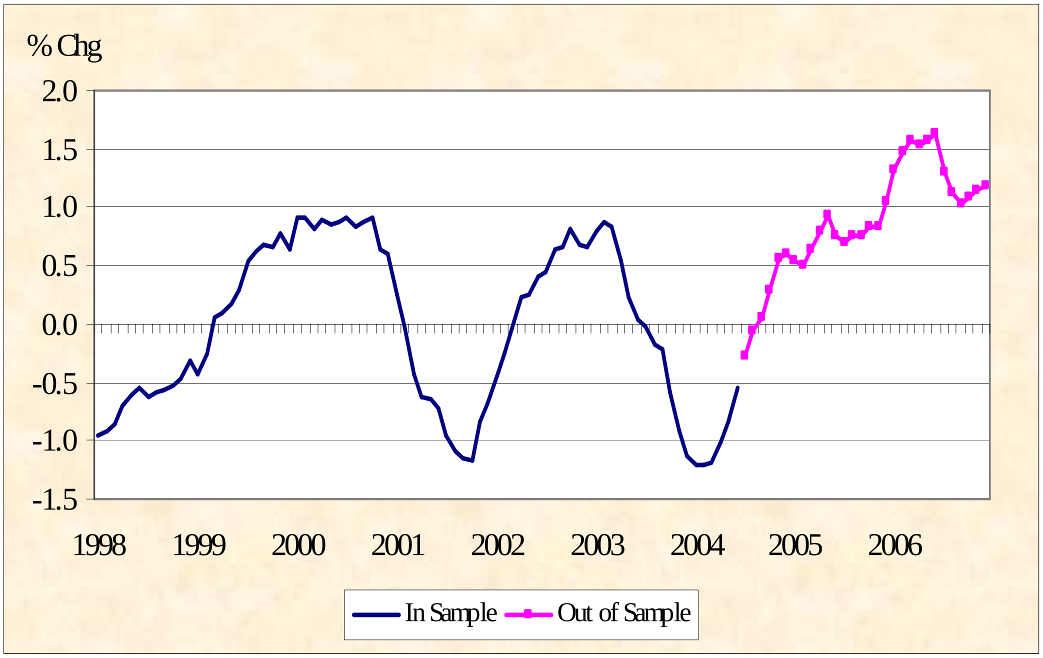


Figure 5.2: Cheddar Cheese Production YOY Change

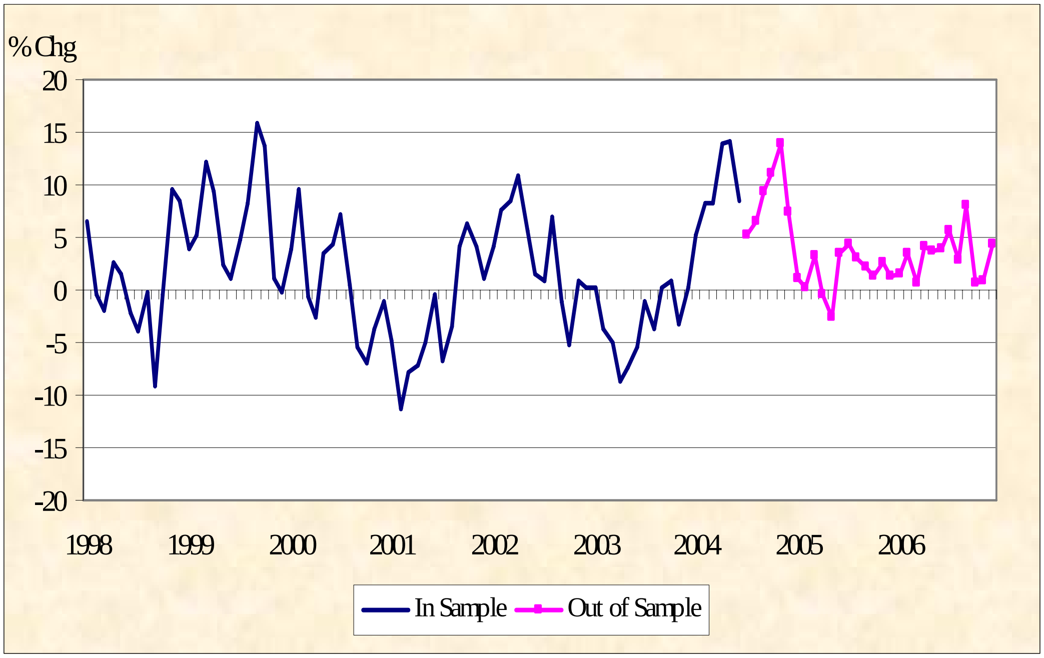


Figure 5.3: Milk to Feed Ratio YOY Change

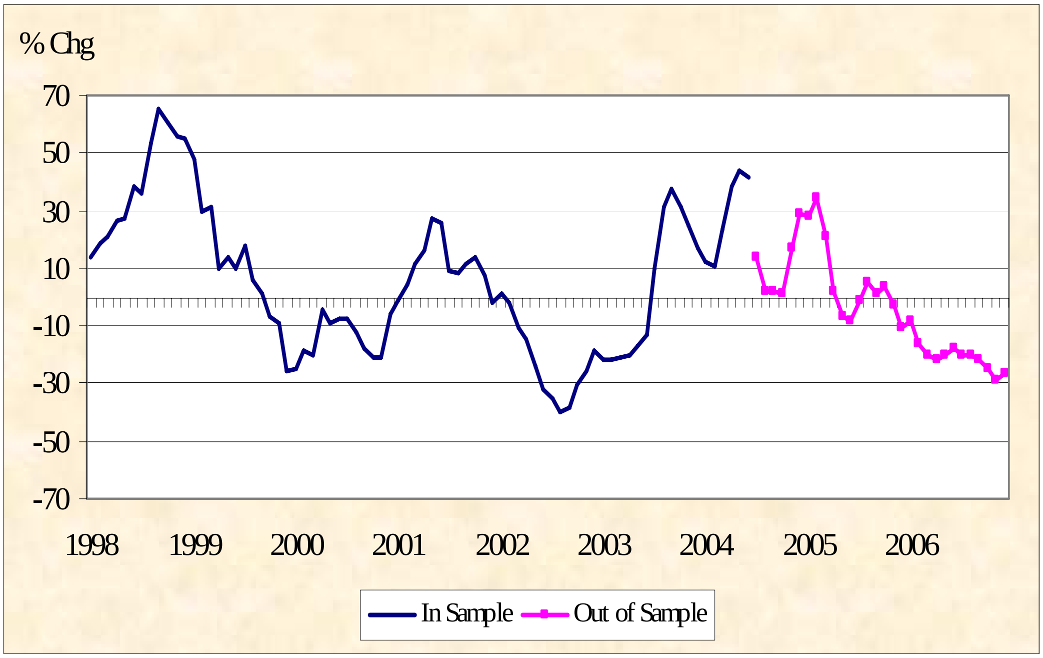
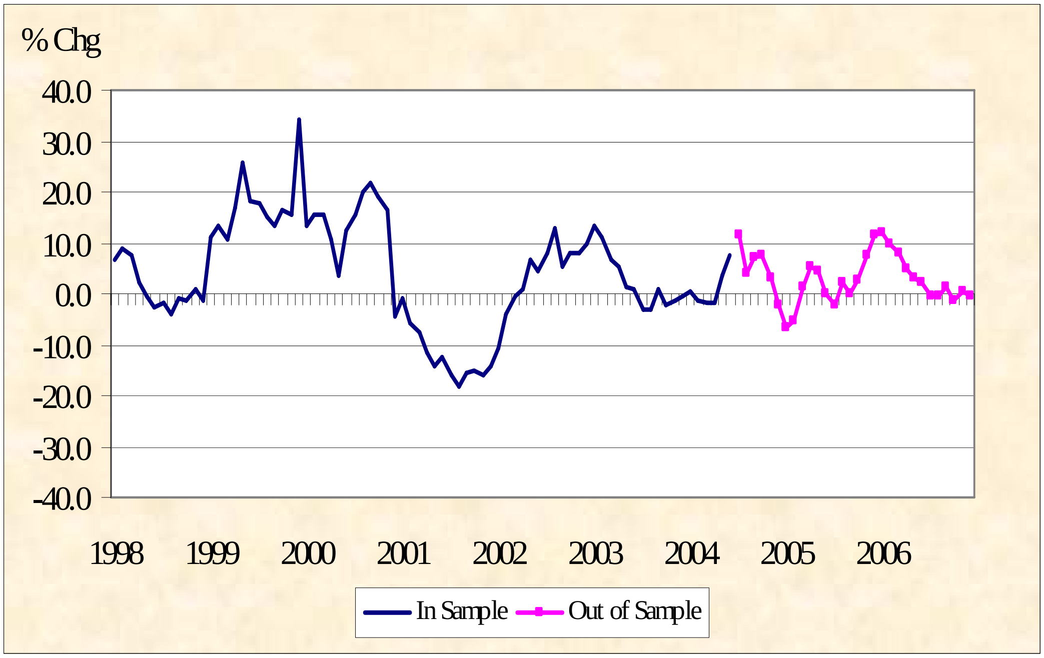


Figure 5.4: American Cheese Stocks YOY Change



Seasonal dummy variables were also included in the Class III prediction model in order to help capture seasonal changes in both supply and demand that were not captured in the independent variables. The dummy variables were based on seasonal quarters with the quarters being determined by a "best-fit" analysis of the monthly mean prices. The first quarter began in February, second in May, third in August, and the fourth quarter began in November.

Table 5.2 lists the text descriptions of the six regressions performed, along with statistics for the R-squared (R2), Mean Standard Error (MSE), Range of Errors (Range), and Mean Absolute Error (MAE).

Table 5.2: Regression Definitions and Analysis

Code	Strategy	Definition	R2	MSE	Range	MAE
G	***3Reg 1***	3-month model uses YOY percentage changes in Cheddar Production (lagged 6 months), Milk-to-Feed Ratio (lagged 4 months), and 20-State Dairy Herd (lagged 5 months)	0.39	4.87	10.15	1.69
H	***3Reg 2***	3-month model uses YOY percentage changes in Cheddar Production (lagged 6 months), Milk-to-Feed Ratio (lagged 4 months), 20-State Dairy Herd (lagged 5 months), and American Cheese in Cold Storage (lagged 5 months)	0.53	3.85	8.06	1.50
I	***3Reg 3***	3-month model uses YOY percentage changes in Cheddar Production (lagged 6 months), Milk-to-Feed Ratio (lagged 4 months), 20-State Dairy Herd (lagged 5 months), and American Cheese in Cold Storage (lagged 5 months); along with seasonal dummy variables.	0.60	3.45	9.22	1.35
O	***6Reg 1***	6-month model uses YOY percentage changes in Cheddar Production (lagged 9 months), Milk-to-Feed Ratio (lagged 7 months), and 20-State Dairy Herd (lagged 8 months)	0.19	6.51	10.61	2.13
P	***6Reg 2***	6-month model uses YOY percentage changes in Cheddar Production (lagged 9 months), Milk-to-Feed Ratio (lagged 7 months), 20-State Dairy Herd (lagged 8 months), and American Cheese in Cold Storage (lagged 8 months)	0.23	6.28	10.85	2.00
Q	***6Reg 3***	6-month model uses YOY percentage changes in Cheddar Production (lagged 9 months), Milk-to-Feed Ratio (lagged 7 months), 20-State Dairy Herd (lagged 8 months), and American Cheese in Cold Storage (lagged 8 months); along with seasonal dummy variables.	0.33	5.74	11.89	1.82

In model development, it was hypothesized that all of the coefficients of the independent variables would be negative. This would mean that with any increase in the independent variable (on a year-over-year basis), would result in a downward movement in price. This hypothesis held true for both the 20-state herd change and for change in cheddar cheese production. However, as both milk-to-feed and American cheese stocks in cold storage increased, so did the Class III price both three and six months into the future.

All of the models meet the two main requirements for use; they use information that can easily be obtained and they are easy to understand. Regression analysis of the predictive models indicates that *3Reg3* and *6Reg3* would best explain the variations in Class III prices and should be used over their contemporaries in the final hedging model.

Tables 5.3 through 5.8 show the results of the econometric analysis performed on different combinations of the independent variables. All of the independent variables were lagged so that the most current information published would be considered in the model on the prescribed execution date.

Table 5.3: Regression Output *3Reg1*

SUMMARY OUTPUT						
Regression Statistics						
Multiple R	0.63					
R Square	0.39					
Adjusted R Square	0.37					
Standard Error	2.21					
Observations	73.00					
ANOVA						
	df	*SS*	*MS*	*F*	*Sig F*	
Regression	3.00	217.77	72.59	14.89	0.00	
Residual	69.00	336.29	4.87			
Total	72.00	554.06				
	Co-eff	*Stnd Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	12.21	0.27	44.66	0.00	11.67	12.76
Cy-6	-0.10	0.05	-2.24	0.03	-0.20	-0.01
MFy-4	0.02	0.01	1.52	0.13	-0.01	0.05
Hy-5	-1.57	0.52	-3.05	0.00	-2.60	-0.54

Table 5.4: Regression Output *3Reg2*

SUMMARY OUTPUT						
Regression Statistics						
Multiple R	0.73					
R Square	0.53					
Adjusted R Square	0.50					
Standard Error	1.96					
Observations	73.00					
ANOVA						
	df	*SS*	*MS*	*F*	*Sig F*	
Regression	4.00	292.51	73.13	19.01	0.00	
Residual	68.00	261.55	3.85			
Total	72.00	554.06				
	Co-eff	*Stnd Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	11.72	0.27	43.81	0.00	11.19	12.25
Cy-6	-0.10	0.04	-2.31	0.02	-0.18	-0.01
MFy-4	0.00	0.01	-0.26	0.79	-0.03	0.02
Hy-5	-3.75	0.67	-5.56	0.00	-5.10	-2.41
ACSy-5	0.14	0.03	4.41	0.00	0.08	0.20

Table 5.5: Regression Output *3Reg3*

SUMMARY OUTPUT						
Regression Statistics						
Multiple R	0.77					
R Square	0.60					
Adjusted R Square	0.55					
Standard Error	1.86					
Observations	73.00					
ANOVA						
	df	*SS*	*MS*	*F*	*Sig F*	
Regression	7.00	330.10	47.16	13.69	0.00	
Residual	65.00	223.95	3.45			
Total	72.00	554.06				
	Co-eff	*Stnd Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	11.22	0.46	24.62	0.00	10.31	12.13
Cy-6	-0.10	0.04	-2.49	0.02	-0.18	-0.02
MFy-4	0.00	0.01	0.10	0.92	-0.03	0.03
Hy-5	-3.50	0.65	-5.36	0.00	-4.80	-2.20
ACSy-5	0.13	0.03	4.19	0.00	0.07	0.19
S1	-0.22	0.62	-0.36	0.72	-1.46	1.02
S2	0.71	0.63	1.13	0.26	-0.55	1.96
S3	1.65	0.62	2.64	0.01	0.40	2.90

Table 5.6: Regression Output *6Reg1*

SUMMARY OUTPUT						
Regression Statistics						
Multiple R	0.44					
R Square	0.19					
Adjusted R Square	0.15					
Standard Error	2.55					
Observations	73.00					
ANOVA						
	df	*SS*	*MS*	*F*	*Sig F*	
Regression	3.00	105.09	35.03	5.38	0.00	
Residual	69.00	448.97	6.51			
Total	72.00	554.06				
	df	*SS*	*MS*	*F*	*Sig F*	*Upper 95%*
Intercept	12.14	0.32	38.47	0.00	11.51	12.77
Cy-9	-0.10	0.05	-1.89	0.06	-0.21	0.01
MFy-7	0.04	0.02	2.24	0.03	0.00	0.07
Hy-8	-0.03	0.59	-0.05	0.96	-1.20	1.14

Table 5.7: Regression Output *6Reg2*

SUMMARY OUTPUT						
Regression Statistics						
Multiple R	0.48					
R Square	0.23					
Adjusted R Square	0.18					
Standard Error	2.51					
Observations	73.00					
ANOVA						
	df	*SS*	*MS*	*F*	*Sig F*	
Regression	4.00	127.02	31.75	5.06	0.00	
Residual	68.00	427.04	6.28			
Total	72.00	554.06				
	Co-eff	*Stnd Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	11.89	0.34	35.14	0.00	11.21	12.56
Cy-9	-0.14	0.06	-2.51	0.01	-0.26	-0.03
MFy-7	0.03	0.02	1.90	0.06	0.00	0.06
Hy-8	-0.93	0.75	-1.24	0.22	-2.43	0.57
ACSy-8	0.07	0.04	1.87	0.07	-0.01	0.15

Table 5.8: Regression Output *6Reg3*

SUMMARY OUTPUT						
Regression Statistics						
Multiple R	0.57					
R Square	0.33					
Adjusted R Square	0.25					
Standard Error	2.40					
Observations	73.00					
ANOVA						
	df	*SS*	*MS*	*F*	*Sig F*	
Regression	7.00	181.17	25.88	4.51	0.00	
Residual	65.00	372.89	5.74			
Total	72.00	554.06				
	Co-eff	*Stnd Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	11.41	0.58	19.59	0.00	10.25	12.58
Cy-9	-0.15	0.06	-2.80	0.01	-0.26	-0.04
MFy-7	0.04	0.02	2.30	0.02	0.00	0.07
Hy-8	-0.62	0.73	-0.85	0.40	-2.07	0.83
ACSy-8	0.06	0.04	1.64	0.11	-0.01	0.14
S1	-0.58	0.80	-0.72	0.47	-2.18	1.02
S2	0.85	0.79	1.07	0.29	-0.73	2.43
S3	1.76	0.80	2.19	0.03	0.15	3.36

5.2 Decision Model for Class III Milk Price Hedging

The development of a model to predict Class III price only satisfies a portion of the objectives of this thesis. To be useful, the Class III price model must be implemented into a decision process by which a producer can make a yes/no decision on whether to hedge the Class III price.

To answer this question, a simple process was implemented to compare the Class III model price with the Class III futures price at the respective three- and six-month periods. Simply, if the Class III futures price on the first business day of the month, three or six months prior to the production month, is greater than the price predicted by the Class III price model, a hedge is initiated. If the futures price is equal to or below the model price, then the hedge is not initiated and the cash market is used.

An additional test was performed on a combination of six-month and three-month decisions. This decision began by using the *6Reg3* model to decide if a hedge was required at the 6-month time frame. If, at this time a hedge was required, the hedge was held through cash settlement. If the decision was deemed "cash," the process was repeated again at the three-month interval using the *3Reg3* price model. If a hedge was required at this time, it would be carried through to cash settlement. If the decision was deemed to be *Cash*, the production will be priced using the USDA announced Class III price at the time of production.

Table 5.9 contains the statistics from each of the Class III pricing models, as well as the combination of *6Reg3* and *3Reg3*, referred to as *Reg3Combo*. All of the model-based hedging strategies increased mean price, relative to the cash market, while decreasing the standard deviation of price around the mean.

Table 5.9: In-Sample Model-Based Class III Hedging Price Statistics

Code	Strategy	Mean	Std Dev	CV	Min	Max	Range	Median
A	***Cash***	12.18	2.77	0.23	8.57	20.58	12.01	11.42
G	***3Reg1***	12.55	2.24	0.18	9.41	20.58	11.17	11.87
H	***3Reg2***	12.64	2.34	0.19	9.37	20.58	11.21	11.87
I	***3Reg3***	12.70	2.36	0.19	9.37	20.58	11.21	11.89
O	***6Reg1***	12.73	2.14	0.17	9.37	20.58	11.21	12.06
P	***6Reg2***	12.63	2.14	0.17	9.54	20.58	11.04	11.89
Q	***6Reg3***	13.02	2.20	0.17	9.75	20.58	10.83	12.15
R	***Reg3 Combo***	12.99	2.12	0.16	9.75	20.58	10.83	12.34

The three strategies that have initiation dates three months prior to the production month are fairly similar. *3Reg1* had the lowest standard deviation of the three at 2.24, with a mean price of $12.55. The minimum price received for *3Reg1* was slightly higher than that received with *3Reg2* and *3Reg3* while all of the 3-month models had a higher minimum price than *Cash*. The maximum price received for all of the models and *Cash* was equal at $20.58. *3Reg1* had the lowest coefficient of variation for all of the models, but only by a small amount.

The mean price for *3Reg2* was $12.64, with a range of $11.21 (max $20.58, min $9.37) and a median price of $11.87. The standard deviation was 2.34 with CV of 0.19. *3Reg*3 had a mean price of $12.70 with a max, min, and range equal to that of *3Reg2*. The median price for *3Reg3* was $11.89, 2 cents higher than *3Reg1* and *3Reg2*. The standard deviation of *3Reg3* was 2.36 with a CV of 0.19.

Looking at the six-month strategies, *6Reg1* has a mean price of $12.73 and a range of $11.21. The maximum price attained was $20.58 while the minimum price was $9.37 and median price was $12.06. The standard deviation of *6Reg1* was 2.14 with a CV of 0.17.

6Reg2 had a mean price of $12.63 with a range of $11.04 (max $20.58, min $9.54) and a median price of $11.89. The standard deviation was determined to be 2.14 with a CV of 0.17. The mean price for *6Reg3* was $13.02, with a range of $10.83 and median price of $12.15. The standard deviation was 2.20 with a CV of 0.17.

The combination strategy (*Reg3Combo*) resulted in a mean price of $12.99 and a range of $10.83. The maximum price was $20.58 (this was the maximum price for all of the model-based strategies), with a minimum price of $9.75 and a median price of $12.34. The standard deviation of this strategy was 2.12 with a CV of 0.16.

5.3 Model-Based Strategy Analysis

The same analysis that was used to determine which systematic hedging strategies were the most beneficial can be used for the model-based strategies. Table 5.10 displays the results of various tests performed on each strategy in an effort to help determine which strategy or strategies should be used in practice.

Table 5.10: In-Sample Class III Model-Based Hedging Strategy Analysis

Code	Strategy	Mean	Std Dev	CV	% Trade[1]	% + Trade[2]	% Cash or +[3]	% Success[4]
R	***Reg3 Combo***	12.99	2.12	0.163	58.9%	86.0%	91.8%	80.8%
O	***6Reg1***	12.73	2.14	0.169	47.9%	74.3%	87.7%	64.4%
Q	***6Reg3***	13.02	2.20	0.169	47.9%	91.4%	95.9%	78.1%
P	***6Reg2***	12.63	2.14	0.170	46.6%	73.5%	87.7%	63.0%
G	***3Reg1***	12.55	2.24	0.179	46.6%	73.5%	87.7%	65.8%
H	***3Reg2***	12.64	2.34	0.185	45.2%	81.8%	91.8%	72.6%
I	***3Reg3***	12.70	2.36	0.186	46.6%	82.4%	91.8%	74.0%
A	***Cash***	12.18	2.77	0.228	0.0%	0.0%	100.0%	100.0%

[1] months of initiated trades/total months
[2] months of initiated positive trades/total months
[3] (months of initiated positive trades plus no trades)/total months
[4] number of "best choice" months/total months

The highest expected Class III price of the model-based strategies was $13.02, from the *6Reg3* strategy. As with the systematic strategies, in months where a hedge was initiated, $0.10 was deducted from the final price to represent transaction costs. There were no costs deducted from months where the cash market was used. The *Reg3Combo* strategy returned a mean price of $12.99, while the *3Reg3* strategy returned a mean price of $12.70. All of the model-based hedging strategies returned mean prices greater than that of the *Cash* strategy.

The standard deviation in all of the model-based strategies was lower than that of the control strategy (*Cash*), but not as low as some seen in the systematic strategies. The lowest standard deviation came from the *Reg3Combo* strategy at 2.12. All of the model-based hedging strategies had standard deviations lower than that of the *Cash* strategy.

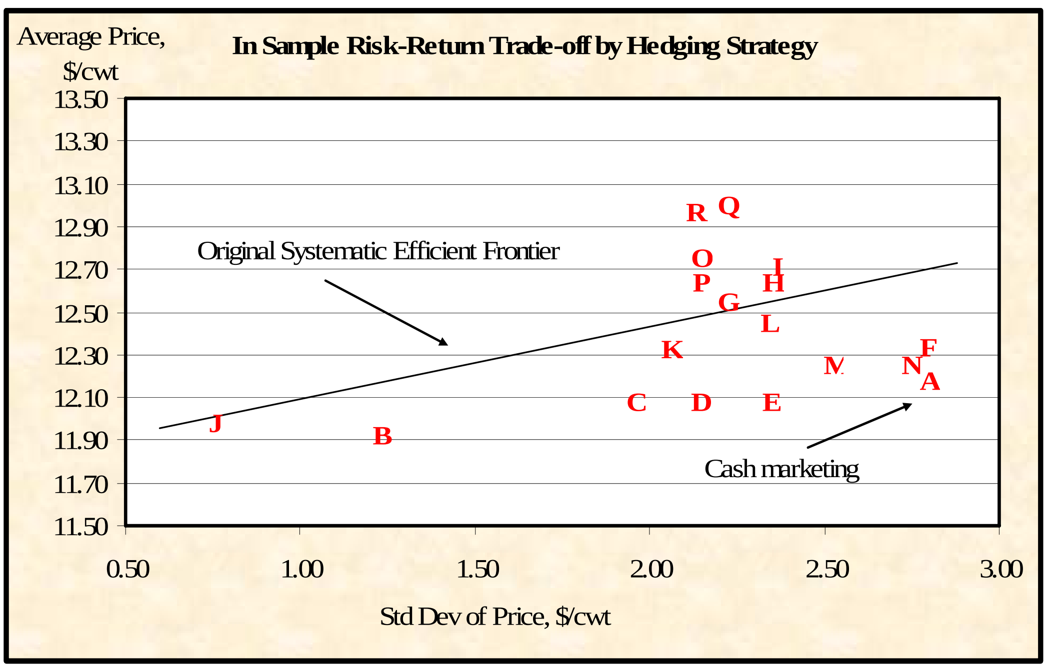
Table 5.10 ranks the model-based strategies by coefficient of variation. The top CV is 0.16 for the *Reg3Combo* strategy, followed by all three of the six-month strategies at

0.17. Again, all of the model-based strategies have CV's lower than the *Cash* strategy, but higher than the *t-6mo* and *t-3mo* systematic strategies presented in Table 4.3.

5.4 Comparison of Systematic and Model-Based Strategies

To evaluate which strategies should be used by producers when developing risk management strategies, an efficient frontier graphic is again utilized. The efficient frontier line was estimated in the same location as in the systematic strategies. The letter codes are defined in Table 4.1 with values identified in Table 4.3 and Table 5.10. This comparison was done using in-sample data. An evaluation of out-of-sample data can be found in Chapter 5.5.

Figure 5.5: Systematic and Model-Based Efficient Frontier



While the safe end of the efficient frontier remains the *t-6mo* strategy (point J), all of the other systematic strategies were eliminated from consideration when the model-based strategies were plotted with them. All seven of the model-based strategies improved the efficient frontier from the frontier that was established solely using the systematic hedging strategies.

Points Q and R represent the highest risk and return points on the efficient frontier. Point Q represents the *6Reg3* strategy, while point R represents the *Reg3Combo* strategy. Both points C (*3mo>$12*) and K (*6mo>$12*) are on the efficient frontier but may not increase return enough to compensate for their higher risk to truly warrant consideration.

When considering the percentage of positive trades resulting from the model-based strategies, the *6Reg3* and *Reg3Combo* models clearly outperformed all of the other strategies with 91.4 and 86.0 percent of hedges being positive. The top three-month strategy was *3Reg3* with 82.4 percent of the months where a hedge was initiated having positive results.

As with the systematic strategies, a success percentage was calculated to determine the percentage of all months where the “best” choice was made between cash or hedging. The top strategy in this category was the *Reg3Combo* approach with 80.8 percent of months being correct. Closely behind was *6Reg3* with 78.1 percent success and *3Reg3* with 74.0 percent success. All of the model-based strategies had higher percentage success calculations than the systematic strategies.

Figure 5.1 clearly demonstrates that there are many hedging strategies that will reduce Class III price risk relative to the unhedged position. Further, many of these strategies will improve upon the mean Class III price. While the choice of hedging strategy hinges on the individual risk preferences of the producer, there are five strategies that meet the rules of the efficient frontier. These strategies include: *t-6mo*, *3mo>$12*, *6mo>$12*, *Reg3Combo*, and *6Reg3*.

Of these five strategies, it is unlikely that *3mo>$12* and *6mo>$12* would be considered due to their poor risk/reward profile as compared to the other three strategies. For producers that wish to minimize risk at all costs, the *t-6mo* strategy greatly reduces the variance in the Class III prices received. *6Reg3* and *Reg3Combo* strategies appear to greatly improve the mean Class III price received while, at the same time, reducing the variance of Class III prices received.

While these strategies cover the two extreme ends of the efficient frontier, it would appear that there is a significant portion of the frontier that can be better served with other hedging strategies. These strategies could include systematic, time-based, or model-based strategies that will provide producers with hedging strategies that would be more “middle-of-the-road” than those presented in this thesis.

5.5 Out-of-Sample Testing Summary

The model-based hedging strategies were also tested out-of-sample just as were the systematic strategies. The out-of-sample period for this testing ranged from July 2004 through December 2006. As was the case with the systematic strategy testing, the model-based strategies performed poorly out-of-sample in comparison to the *Cash* strategy. Table 5.11 lists the performance statistics for each of the strategies during the out-of-sample test.

Unlike the in-sample testing where the *Cash* strategy performed relatively poorly, during the out-of-sample period the *Cash* strategy had both the lowest standard deviation and coefficient of variation at 1.44 and 0.11. In addition, the mean price for the *Cash* strategy of $13.33 was bested by only one of the model-based strategies and that was only by 2 cents.

Table 5.11: Out-of-Sample Class III Model-Based Hedging Strategy Analysis

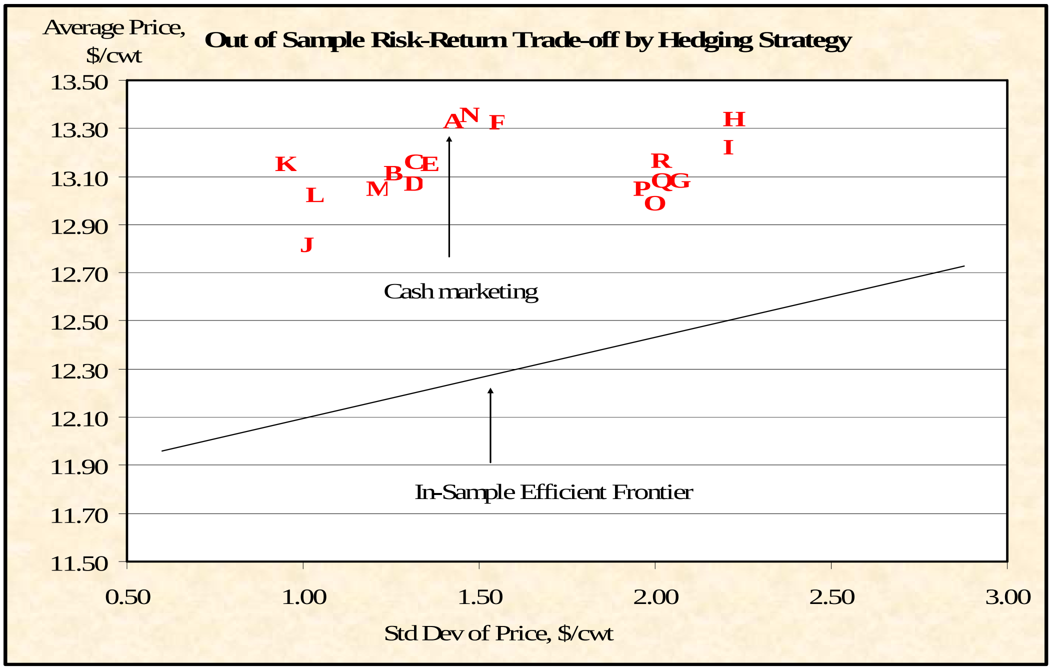
Code	Strategy	Mean	Std Dev	CV	% Trade[1]	% + Trade[2]	% Cash or +[3]	% Success[4]
A	***Cash***	13.33	1.44	0.108	0.0%	0.0%	100.0%	100.0%
P	***6mo Reg2***	13.07	1.95	0.149	93.3%	46.4%	50.0%	46.7%
Q	***6mo Reg3***	13.09	1.99	0.152	83.3%	48.0%	56.7%	50.0%
O	***6mo Reg1***	12.99	1.98	0.153	96.7%	44.8%	46.7%	43.3%
R	***Reg3 Combo***	13.16	2.02	0.153	93.3%	57.1%	60.0%	46.7%
G	***3mo Reg1***	13.10	2.06	0.157	100.0%	46.7%	46.7%	40.0%
H	***3mo Reg2***	13.35	2.21	0.165	86.7%	53.8%	60.0%	53.3%
I	***3mo Reg3***	13.23	2.20	0.166	86.7%	50.0%	56.7%	46.7%

[1] months of initiated trades/total months
[2] months of initiated positive trades/total months
[3] (months of initiated positive trades plus no trades)/total months
[4] number of "best choice" months/total months

The two strategies that performed well in the in-sample testing (*Reg3Combo* and *6Reg3*) did not exhibit the same performance in the out-of-sample testing and were arguably no different than any of the other model-based strategies. Statistics for percentage of positive trades and percentage success were considerably lower in the out-of-sample testing and were similar to the results seen in the systematic strategy out-of-sample testing.

Figure 5.6 shows the efficient frontier graph of the out-of-sample results. While the efficient frontier has clearly moved up (indicating higher returns for nearly the same level of risk) it is interesting to see the dramatic change in the *Cash* strategy. During the in-sample testing, *Cash* was plotted in the lower right quadrant of the graph (the lowest return and highest risk quadrant) while in the out-of-sample, it has moved much higher and further to the left on the graph (indicating greater return with less risk).

Figure 5.6: Systematic and Model-Based Efficient Frontier



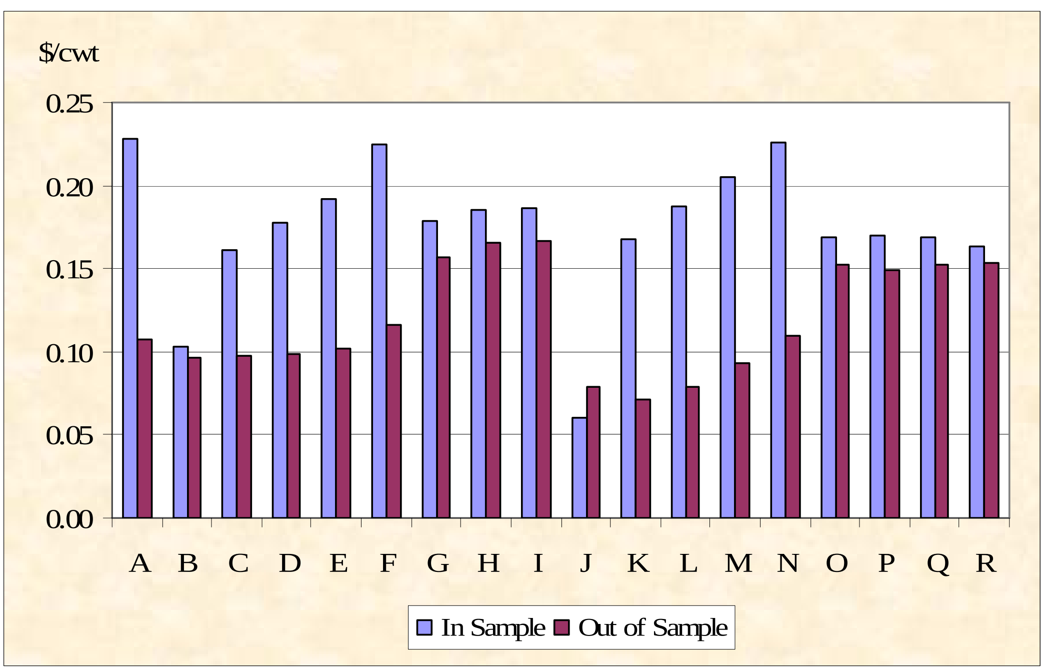
While the *Cash* strategy, in a relative sense, improved markedly from the in-sample to out-of-sample tests, there was also significant improvement in the *6mo>$12* (point K) strategy which was on the efficient frontier in both tests. Out-of-sample, *6mo>$12* had a mean return of $13.17 and a standard deviation of 0.94. This compared to a mean return of $13.33 and a standard deviation of 1.44 for *Cash*.

It is also important to note that the high return strategies on the efficient frontier from the in-sample testing (*6Reg3* and *Reg3Combo*) remained consistent in their mean return and standard deviation out-of-sample, but did not show the improvement that the

Cash or the systematic strategies had during the out-of-sample period. In fact, all of the model-based strategies had mean returns and standard deviations during the out-of-sample testing that were consistent with their in-sample testing.

Figure 5.7 is a graphical illustration of the coefficient of variation for each of the strategies during in-sample and out-of-sample testing. The graph clearly shows a distinct decrease in the CV for the *Cash* (A) and price-triggered systematic strategies while only a small decrease in the CV for the model-based strategies. The only systematic strategies that remained consistent were *t-3mo* (B) and *t-6mo* (J), which initiate a hedge no matter what the cash price is. While each of these two strategies had an increased mean price in the out-of-sample test versus the in-sample, they did not experience a significant decrease in standard deviation as the other systematic strategies did.

Figure 5.7: Coefficient of Variation Comparison for all Strategies



CHAPTER 6: CLASS III MILK PRICE BASIS MODEL

6.1 Determining Milk Basis

Basis prediction has consistently been difficult in the dairy industry. Basis is defined as the cash price of a commodity minus the futures price of that commodity. For Class III milk, basis is always zero since all Class III milk is priced equally by the government. Thus, a producer who is hedging Class III milk with a futures contract and allowing the contract to be cash-settled (holding the contract through expiration) will be assured of having a zero basis for their Class III milk. Unfortunately, producers sell more than just Class III milk. They also sell Class I, II, and IV milk, which results in an actual price (mailbox price) that is significantly different than that of Class III, milk resulting in a basis that is not zero. For the purposes of this thesis, basis is defined as the mailbox price minus the announced Class III price.

The Class III price is made up of standardized prices for the fat, protein, other solid components of milk, and milk quality. Not only are producers paid for levels above these standards, they are penalized for not meeting the standard since they will be selling fewer pounds of components than those that have met or exceeded the standard. Further, producers may be paid additional premiums based upon milk quality and quantity, as well as premiums above and beyond the individual component prices (Jesse and Cropp, 2004).

The final factor in predicting milk basis is the producer price differential (PPD). This is a calculation designed to allow all producers within a Federal Milk Marketing Order to pay an equal "base" price for milk. Basically, it takes money from processors selling higher valued products and gives it to processors selling lower value products. This allows the processor that is selling lower value products to compete evenly with processors selling the higher value products.

While milk distribution and consumption patterns are predictable by nature, prices of individual classes of milk are not so predictable. Since only Class I and II processors are required to remain in the pools during each production month, PPD's will fluctuate and can be very unpredictable.

6.2 Milk Basis Model

There are numerous independent variables that can be evaluated when trying to explain the movement in the dependent variable, milk basis. This thesis will evaluate changes in price in the two months leading up to the production month, as well as past basis figures for the production month.

Seasonal factors play a significant role since weather patterns will change the component make-up of raw milk and the consumption patterns of consumers. Changes in component percentages and milk quality are strongly correlated to environmental changes that individual herds are subjected to (Drye and Cropp, 2002). To capture this change, the basis model will include the same seasonal dummy variables as used in the Class III model.

The second portion of the basis model attempts to explain changes in the dependent variable by addressing PPD. Bamba and Maynard (2004) concluded that there was a negative correlation between Class III milk prices and basis. To address changes in PPD, the Class III prices for the two months prior to the production month have been evaluated to determine if these changes have value in explaining changes in the dependent variable.

Table 6.1 lists and defines the independent variables that were evaluated for their ability to explain the dependent variable. Table 6.2 describes the various regressions that were evaluated for the predictive ability. The table also lists four naïve strategies that were evaluated. Table 6.3 ranks the regressions by their R-square value. It also provides the mean standard error, range, and mean absolute error of the various regressions.

Table 6.1: Basis Model Variable Definitions

Variable	Definition
CIII	Actual Class III price for production month
B	Actual Class III basis
t	Projected production month
Bt-12	Actual basis 12 months prior to projected month
t-3	Class III price of projected month on first business day, 3 months prior to delivery
t-6	Class III price of projected month on first business day, 6 months prior to delivery
3p-1	Class III futures price of the month one month proceeding projected month - 3mo
3p-2	Class III futures price of the month two months proceeding projected month - 3mo
6p-1	Class III futures price of the month one month proceeding projected month - 6mo
6p-2	Class III futures price of the month two months proceeding projected month - 6mo
t3ch1	(t-3) minus (3p-1)
t3ch2	(t-3) minus (3p-2)
t6ch1	(t-6) minus (6p-1)
t6ch2	(t-6) minus (6p-2)
S1	Seasonal dummy variable for Feb - Mar - Apr production month
S2	Seasonal dummy variable for May - Jun - Jul production month
S3	Seasonal dummy variable for Aug - Sep - Oct production month
S4	Seasonal dummy variable for Nov - Dec - Jan production month

Table 6.2: Definitions of Basis Prediction Models

Regression		Definition
Reg 1	3mo	Model uses only futures price
Reg 2	3mo	Model uses futures price with seasonal dummy variable
Reg 3	3mo	Model uses futures price, futures price of the month proceeding production, and seasonal dummy variable
Reg 4	3mo	Model uses futures price, futures prices of both the month proceeding production and two months preceding production, and seasonal dummy variable
Reg 5	3mo	Model uses futures price, futures price of the month 2 months proceeding production, and seasonal dummy variable
Reg 6	3mo	Maynard/Bamba model. Uses futures price, actual basis 12 months prior to production month, and seasonal dummy variables.
Reg 14	3mo	Model uses seasonal dummy variables only
Reg 15	3mo	Model uses change in futures prices {(t-3)-(3P-2)} plus seasonal dummy variables
Reg 16	3mo	Model uses change in futures prices {(t-3)-(3P-1)} plus seasonal dummy variables
Reg 7	6mo	Model uses only futures price
Reg 8	6mo	Model uses futures price with seasonal dummy variable
Reg 9	6mo	Model uses futures price, futures price of the month proceeding production, and seasonal dummy variable
Reg 10	6mo	Model uses futures price, futures prices of both the month proceeding production and two months preceding production, and seasonal dummy variable
Reg 11	6mo	Model uses futures price, futures price of the month 2 months proceeding production, and seasonal dummy variable
Reg 12	6mo	Maynard/Bamba model. Uses futures price, actual basis 12 months prior to production month, and seasonal dummy variables.
Reg 13	6mo	Model uses seasonal dummy variables only
Reg 17	6mo	Model uses change in futures prices {(t-6)-(6P-2)} plus seasonal dummy variables
Reg 18	6mo	Model uses change in futures prices {(t-6)-(6P-1)} plus seasonal dummy variables
t-12		Basis is simply equal to actual basis 12 months prior to projected month.
t-6		Basis is simply equal to actual basis 6 months prior to projected month.
t-3		Basis is simply equal to actual basis 3 months prior to projected month.
3-yr. Ave.		Basis is simply equal to actual averaged basis of projected month during the previous three years.

Table 6.3: Basis Model Regression Results

Regression	R-square	MSE	Range	MAE
Reg 1	0.07	0.48	3.37	0.52
Reg 2	0.34	0.36	2.83	0.45
Reg 3	0.35	0.36	3.01	0.44
Reg 4	0.37	0.35	2.82	0.44
Reg 5	0.34	0.36	2.94	0.45
Reg 6	0.34	0.37	2.83	0.45
Reg 14	0.28	0.38	2.68	0.49
Reg 15	0.31	0.38	3.01	0.47
Reg 16	0.32	0.37	3.00	0.46
Reg 7	0.00	0.52	3.48	0.55
Reg 8	0.28	0.39	2.67	0.49
Reg 9	0.28	0.39	2.67	0.49
Reg 10	0.29	0.40	2.68	0.49
Reg 11	0.29	0.39	2.68	0.49
Reg 12	0.28	0.39	2.71	0.48
Reg 13	0.28	0.38	2.68	0.49
Reg 17	0.29	0.39	2.68	0.49
Reg 18	0.28	0.39	2.67	0.49
t-12	N/A	N/A	3.41	0.69
t-6	N/A	N/A	4.42	0.75
t-3	N/A	N/A	4.89	0.85
3-yr. ave	N/A	N/A	3.55	0.54

6.3 Milk Basis Model Summary

All of the basis models were tested at six and three months prior to the production month. The base for the models was predicated on work done by Bamba and Maynard (2004). Their basis model used seasonal dummy variables, along with independent variables for actual basis twelve months prior to the production month and the futures price of the production month.

The basis models tested in this thesis began at a single futures price for the production month and added independent variables until all independent and dummy variables were included in the model. The models that tested the highest in both the three-and six-month categories included the production month futures price, the futures prices of the two months directly proceeding the production month, and seasonal dummy variables.

There is a clear distinction between the explanatory values of the regressions calculated at three months prior to the production month and those calculated six months prior to the production month. As shown in the systematic hedging strategies earlier, Class III prices six months prior to the production month tend to be much less volatile than the actual Class III price. Because the PPD portion of basis is predicated on volatility in the two months leading up to the production month, it makes sense that the six-month basis models do not show the same predictive ability as the three-month models.

The highest R-square value was 0.37 from *Reg 4*, a three-month model that incorporated the production month futures price, the futures prices of the two months directly proceeding the production month, and seasonal dummy variables. The 0.37 R-squared values indicate that 37 percent of the variability in the basis can be explained by the model. While this is not a "highly predictive" model, it did have the highest R-square of the models tested.

As expected, the models that incorporated only the seasonal dummy variables or Class III price variables performed poorly. This would further validate the need to have both price and seasonal variables in the basis model in order to incorporate both the seasonal component differences and the price-related PPD variances into the model.

From June of 1998 through June of 2004, basis in the Upper Midwest Milk Marketing Order averaged $1.30 with a minimum of -$0.47 and a maximum of $2.99. The standard deviation of this basis series was 0.72. The best predictive 3-month model had a mean absolute error of $0.44. The best mean absolute error of the six-month models was $0.48. The mean absolute error for all of the models ranged from $0.44 to $0.55. The MAE for the systematic prediction models tested ranged from $0.54 to $0.85.

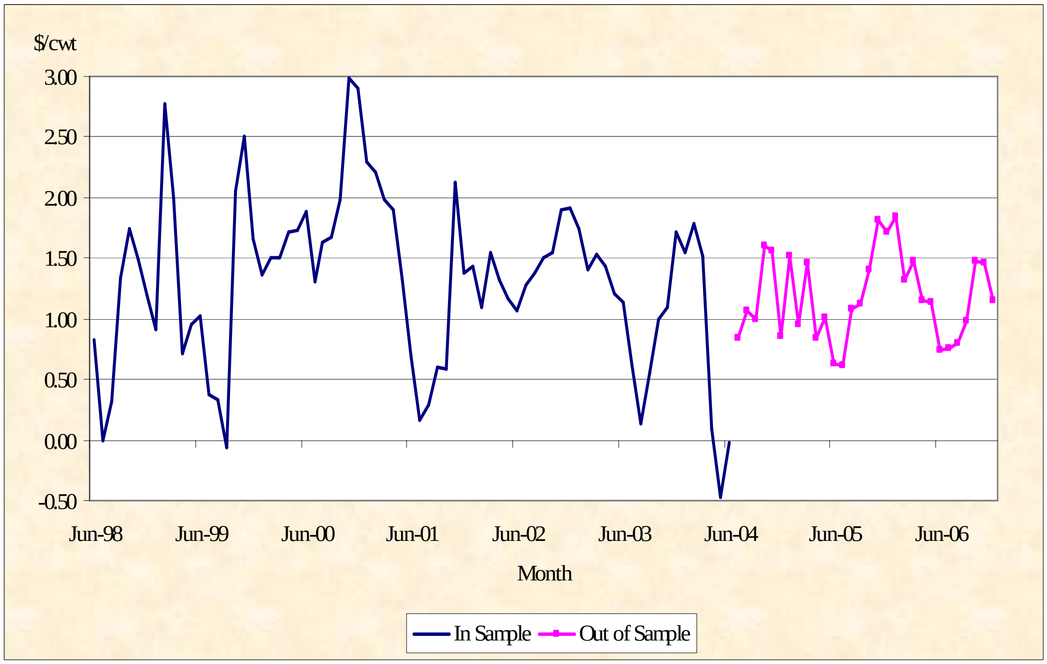
In addition to the regression models, four naïve models were tested for their basis prediction ability. These models were *t-12* (the basis from the same month one year earlier), *t-6* (the basis from six months prior to the production month), *t-3* (the basis from three months prior to the production month), and *3-yr. ave* (the average basis of the production month from the previous three years).

The only naïve basis prediction model that showed promise was *3-yr. ave* which had a MAE of $0.54 and a range of errors of $3.55. Because of the seasonal influences on basis, it is logical that *3-yr. ave* is a solid basis prediction tool, but it lacks the ability to adjust for rapidly changing current Class III milk prices. This likely is the reason this model failed to outperform a majority of the regression-based models in-sample.

6.4 Out-of-Sample Testing

Each of the basis prediction models was tested for performance during an out-of-sample period ranging from July 2004 through December 2006. Figure 6.1 plots the in-sample and out-of-sample average basis levels experienced in the Upper Midwest milk marketing order. As the graph shows, basis volatility appears to be smaller during the out-of-sample period in relationship to the in-sample period.

Figure 6.1: Historical Milk Basis



The mean basis during the out-of-sample period was 12 cents less than the in-sample period at $1.18. The standard deviation of basis during the out-of-sample period was 0.35, much less volatile than the in-sample period, which had a standard deviation of 0.72.

This reduction in volatility may help to explain the improved results of the basis prediction models out-of-sample. The models ranged in MAE from $0.24 to $0.35, a much smaller range than seen in-sample. The range of errors for the models were also greatly reduced from $2.67-$3.48 in-sample to $1.23-$1.71 in the out-of-sample test.

Table 6.4 lists the results of the out-of-sample testing for each of the models. All of the regression-based models showed improvement in their predictive abilities as measured by mean absolute errors and range of errors. While this is a positive result and shows that the regression-based basis prediction models may be successfully used, they did not out-perform the *3-yr. ave* model, which had a MAE of $0.22 and a range of errors of $1.36.

The performance of this model was likely helped during the sample period by a significant reduction in Class III price volatility. It is important to note that while this model appears to be the most logical to use because of its ease of use, it will have a reduced predictive ability during periods of increased Class III price volatility.

Table 6.4: Basis Model Regression Results – Out-of-Sample

Regression	Range	MAE
Reg 1	1.45	0.24
Reg 2	1.71	0.32
Reg 3	1.67	0.30
Reg 4	2.01	0.35
Reg 5	1.67	0.30
Reg 6	1.70	0.32
Reg 14	1.49	0.26
Reg 15	1.51	0.24
Reg 16	1.68	0.25
Reg 7	1.23	0.32
Reg 8	1.47	0.26
Reg 9	1.52	0.26
Reg 10	1.52	0.25
Reg 11	1.52	0.25
Reg 12	1.50	0.26
Reg 13	1.49	0.26
Reg 17	1.54	0.25
Reg 18	1.53	0.26
t-12	2.33	0.39
t-6	2.37	0.52
t-3	3.11	0.66
3-yr. ave	1.36	0.22

CHAPTER 7: SUMMARY AND CONCLUSIONS

7.1 Summary of Thesis Objectives

The main objective of this thesis was to determine whether or not Class III price risk can be reduced through the use of a model-based hedging strategy. In-sample statistical analysis of the seven model-based hedging strategies purported by this thesis revealed that price risk could be reduced by a producer's consistent use of one of the models. Producers who only used the *Cash* method of marketing milk during the in-sample period encountered a Class III price standard deviation of 2.77 while the model-based strategies had standard deviations that ranged from a low of 2.05 to a high of 2.33. All of the model-based strategies reduced price volatility.

In addition to reducing Class III price volatility, all seven of the model-based hedging strategies improved upon the mean Class III price received of $12.18, during the in-sample period beginning June 1998 through June 2004. The model-based hedging strategies returned a Class III price during that same time frame that averaged between $12.54 and $13.02, after taking into account hedging and interest costs.

Outside of risk reduction, the objectives of this thesis clearly stated that the Class III models used in the strategies needed to be easily understood by the average milk producer and employ information that is readily available. The four independent variables used in this analysis are all reported on a monthly basis by the National Agricultural Statistics Service and the seasonal dummy variables are constant. The futures prices used to determine whether or not a contract is placed are publicly reported by the Chicago

Mercantile Exchange free of charge on a ten-minute delayed basis. These all satisfy the "readily available" doctrine.

As for being easily understood by the average producer; the model itself and its conceptual basis may be somewhat difficult to understand. The decision strategy, however, is extremely straight forward in that a producer only needs to look at two numbers to determine if the model price is higher or lower than the futures price of the month being modeled. From there, the decision is simply to hedge the production month's Class III price or use the cash market.

Unfortunately, the out-of-sample testing period from July 2004 through December 2006 revealed contradictory conclusions. During the out-of-sample period, the *Cash* strategy improved markedly over the model-based strategies with a mean price of $13.33 versus a range of $12.99-$13.35 for the models. In addition, the standard deviation of price for *Cash* during the out-of-sample period was 1.44 while the models ranged from 1.95-2.21. Using both coefficient of variation and efficient frontier decision making tools, the *Cash* strategy would have been the choice over the models during the out-of-sample test. This result would indicate that the Class III futures market is efficient in that any reduction in price volatility would come at a reduction in mean return.

In addition to the main objective, this thesis also had three sub-objectives. The first and second of these was to identify the primary systematic Class III hedging strategies used in the dairy industry today and to perform an analysis on them to determine their risk reduction features. Five distinct strategies were identified and analyzed at both three- and six-months prior to the production month dates. The results of these strategies were then compared to the “cash” strategy to deduce their risk-reduction characteristics.

Of the ten strategies analyzed (five strategies in two time horizons), three reduced price volatility in the in-sample test beyond what was seen in the model-based strategies. The lowest standard deviation was 0.73 from the *t-6mo* strategy, followed by *t-3mo* at 1.22, and *3mo>$12* at 1.95. The standard deviations of *3mo>84*% and *6mo>84%* were basically unchanged from *Cash* largely because they were only initiated in 4 and 1 months out of 73, respectively. The remaining strategies had standard deviations that ranged from 2.06 to 2.51.

Of the strategies that had volatility levels lower than *Cash*, four met the “efficient frontier” test. Those strategies were *t-6mo*, *3mo>$12*, *6mo>$12*, and *6mo>ave*. Each of these strategies would present producers advantages over the *Cash* market depending upon the risk tolerances of the individual producers using the strategy. Two of the strategies, *t-6mo* and *3mo>$12* had a mean Class III price lower than that of the *Cash* market at $11.95 and $12.06, respectively. The strategies *6mo>$12* and *6mo>ave* had mean Class III prices of $12.31 and $12.47, respectively.

The out-of-sample testing of the systematic strategies was somewhat more favorable than the results of the model-based strategies. The majority of the systematic strategies had standard deviations lower than the *Cash* standard deviation of 1.44. *6mo>$12* had the lowest standard deviation at 0.94 followed by *6mo>ave* and *t-6mo* at

1.02. Only *6mo>84%* and *3mo>84%* had higher standard deviations than *Cash* at 1.46 and 1.55, respectively.

Of the low standard deviation strategies, *6mo>12* had a mean price of $13.17, *6mo>ave* was $13.03, and *t-6mo* was $12.85. All of these strategies had a lower mean price than the $13.33 of the Cash strategy.

Based upon the efficient frontier decision making tool, *6mo>12*, *3mo>12*, *Cash*, and *6mo>84%* are viable pricing strategies during the out-of-sample test. The only strategy that was on the efficient frontier in both the in-sample and out-of-sample testing was *6mo>$12*.

Based upon the coefficient of variation decision making tool, all of the systematic strategies outside of *6mo>84%* and *3mo>84%* would have been acceptable choices ahead of *Cash*. This was not the case when comparing *Cash* to the model-based strategies. There, *Cash* would have easily been the best choice when comparing CV.

The final sub-objective of this thesis was to develop a model that would predict milk basis three and six months prior to the production month. The foundation of the models tested was that basis was divided into two segments. The first was a milk component and quality portion that is mainly variable on a seasonal basis. The second was the Producer Price Differential that is mainly affected by rapid changes in the prices of Class I, II, and IV milk.

There were twenty-two basis models tested for this thesis. Of these models, the mean absolute errors ranged from 0.44 to 0.85 during the in-sample test. The average milk basis during this time frame was $1.30. The models were also tested out-of-sample, where relative performance improved over the in-sample period. The majority of the improvement in performance can be attributed to significantly lower volatility in basis levels during the out-of-sample test period. While the majority of the models tested did give a general direction in what the basis during the production month may be, none of the models were able to outperform the naïve basis prediction model of simply taking the average of the last three years basis for the individual production month.

7.2 Research Limitations

The main limitation to the research in this thesis is the small number of months that Class III (BFP) futures contracts have been trading. Class III futures began trading in 1996 at the New York Mercantile Exchange (Cropp and Stephenson, 1995). It wasn't until 1997, when the Chicago Mercantile Exchange also began trading milk futures, that volume reached a level where analysis was meaningful. Since the completion of the in-sample portion of this study, Class III milk futures trading volumes have steadily increased and the number of months with contracts trading has nearly doubled. These changes likely would have an impact on the analysis performed in this study (presumably positive).

There were also significant limitations in the consistency of data used in this study. Because one of the guidelines of the study was to incorporate information that would be readily available to dairy producers, only USDA reported numbers were used. It became obvious during the study that significant revisions to USDA's reported data could be made as far as one year from the original reporting date. The original idea was to keep the data being used as current as possible, but this may have skewed the results of the study because of the large number of revisions made by USDA.

7.3 Future Research Opportunities

As previously mentioned, more model-based strategies need to be developed in order to fill in the "gaps" in the efficient frontier. This thesis found what appeared to be the risk-adverse end of the frontier and the opposite, more risky, end of the curve. There is a considerable portion of the frontier's "middle ground" where additional strategies would appeal to certain producers. It is also likely that further research into hedging and pricing strategies would reveal strategies that would be safer on the efficient frontier, as well as, those that would return a greater mean price for an added level of risk.

This thesis study focused on incorporating supply-side data into a model to attempt to predict Class III milk prices. While this may have been possible during years where the government had large influences on price, it is a naïve approach to predicting today's complicated dairy supply and demand picture. The demand side of the traditional supply-demand economic equation needs to be included into this type of model if there is a chance of success. At the present time, dairy demand information is limited and costly to obtain. In time, it is possible the cost of obtaining this information will decrease and it will become more available for inclusion into this type of study.

This thesis failed to develop and prove a realistic milk basis model. The thesis continued to work on the foundation of basis prediction started by many dairy economists throughout the country, but an accurate predictive model remains elusive.

While it is the intent of this thesis to provide a model for hedging Class III milk, as other models become available and information changes in cost, scope, and quality, more research will need to be performed in order for model-based strategies to remain successful. The thesis did reveal that incorporation of systematic hedging strategies for Class III milk has the potential to significantly and consistently lower the volatility of Class III milk prices. While there is a cost to using these strategies (lower mean price than the cash market), this should be expected in an efficient market.

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