THESIS

FORECASTING CLASS III MILK PRICES IN A VOLATILE MARKET

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ABSTRACT

FORECASTING CLASS III MILK PRICES IN A VOLATILE MARKET

Repeated experiences of volatility with Class III milk prices have caused many producers, wholesalers, and retailers to avoid risk management decisions involving the Class III milk price; instead market participants realize profits as they occur without managing their financial environment based on their expectations. This research forecasted Class III milk price from August 2012 to July 2014 using data from January 2000 to July 2012. The conclusions of this study found that the unrestricted vector autoregressive model is the best forecast both for ex-post and out-of-sample methods. Additionally, it was determined that the futures prices are not strong reflections of feed costs, although one to four months prior to expiration the futures contract price reflects the current feed costs to some degree. Also six to eight months prior to contract expiration there is little movement in the contract price, and the previous month's price has a large influence on the current month's price during this time. It can be concluded that the futures contract price is largely driven by current market conditions during the remainder of the time prior to contract expiration.

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CHAPTER 1: INTRODUCTION

Extreme price volatility occurring within Class III milk prices has led many producers to expect the unexpected and turn away from opportunities to manage risk associated with production. Class III milk is a commodity product and thus the price is market driven for which events in the market can lead to responses throughout the entire supply chain. Market influences such as increased feed costs, cattle inventory reductions, and fluctuating milk prices have caused much volatility throughout the entire supply chain. Events like increasing feed costs despite high milk prices in 2011 triggered decreases in equity by the dairy producers. However, despite the low margins producers continued to increase inventories as a result of high prices and an expectation of decreasing feed costs. Now, faced with high milk supply, low milk prices, and high feed input costs as a result of the drought in summer 2012, cow inventory reductions are beginning to take place (LMIC, 2012). Volatility is likely to occur throughout the coming year as a response to these market influences (Johnson, 2012).

A portion of this volatility is beneficial to the market and allows the market to adjust itself to changing levels of supply and demand. However, the problem arises when the market is unable to expect these price changes and is faced with an under or over supply of milk; both scenarios result in price fluctuation. As a result of the drought in 2012, exasperating an already tense dairy market from 2011, producers and other participants in the market will continue to be faced with market volatility. The price fluctuations will force producers, wholesalers, retailers, and consumers to manage risk through price forecasts and hedging or face the possibility of bankruptcy. Risk management will allow market participants to increase their profits or at least manage their losses to remain in business until the situation improves.

For many participants in the dairy market, cheese is a major driver of milk price. For producers who receive a composite price for their milk, the base of this composite is termed a Class III milk price. This Class III milk price is the minimum price a producer will receive per hundredweight (cwt.) for their milk. Milk which is classified as Class III is used in the production of cheese. Thus, producers and processors of cheese must pay the Class III milk price for the milk they use in the production of the various types of cheese and whey (a by-product of cheese processing). The processing level of the market is referred to as the wholesaler and they will receive a price per lb. from the retailer for the cheese they produce. The retailer then sells the cheese to the consumer also on a price per lb. basis.

By developing forecasting models for Class III prices, projections will allow market participants to anticipate future market conditions and make management decisions to mitigate the risk of high feed prices and other input factors and relatively low output prices received. These forecasting models are designed to improve the end result for producers looking to manage risk and hedge their positions in both the feed input side of the market and also in the production of milk. Additionally, the models will serve as a risk management tool for companies within the industry looking to maximize profits through hedging cheese purchases.

1.1 Objective

The objective of this study is to develop a Class III milk price-forecasting model. This forecasting model will be applicable to producers and other market participants and provide a framework for an analysis of the risk associated with cheese purchases. More specifically, six forecasting models, which account for the impact of cheese exports and the influence of milk profit, will be developed and tested using an ex-post method to determine which models work best and are the most reliable in forecasting cheese prices. Additionally, out-of-sample forecasts of Class III milk prices will be conducted for August 2012 to July 2014. The final objective of this thesis is to determine the hedging horizon associated with Class III milk futures contract and the relationship the price of the futures contract shares with feed costs.

1.2. Organization of the Thesis

The following chapter will provide background and introduction to the dynamics occurring within the dairy market. A discussion of previous literature will also be included concerning preceding forecasting models and risk management strategies, and also the contributions of this thesis to the literature. Chapter 3 will detail the methodology behind the six forecasting models constructed and compared in this thesis, along with methodology for formulating rational pricing procedure. An initial section of this chapter will look at the methodology behind the foundational models. Chapter 4 will discuss the data used within the model and the summary statistics and correlation between the variables. Chapter 5 will include the results and discussion for price forecasts into 2014 along with the hedging analysis. Chapter 6 is the final conclusion of the thesis and recommendations for future research.

CHAPTER 2: LITERATURE REVIEW

This chapter is divided into five sections. Section 2.1 contains a literature review of previous dairy market research, specifically pertaining to price forecasting models and risk management. Research addressing total milk production and the relationship between cheese price and Class III milk price is also contained within the literature review. The second section (Section 2.2) is concerned with dynamics occurring within the dairy market and the milk pricing classification system. Section 2.3 describes interactions within the supply chain while Section 2.4 addresses Class III milk price and the volatility which occurs in that market. Finally, Section 2.5 discusses the contributions this research makes to the literature.

2.1 Forecasting Models and Risk Management

Forecasting models for milk price and other dairy product prices are heavily influenced by the milk supply and demand. According to Mosheim (2012) “the relationship between aggregate milk supply and aggregate milk demand drives the dairy industry toward equilibrium based on changes in the all-milk price” (Pg. 2). It is essential that this relationship of supply and demand of milk is maintained while forecasting Class III milk price and the resulting impact it has on cheese price for other industry participants. Class III milk price will be used as a substitute of All Milk Price (AMP) because it is the minimum price producers would receive for milk, while AMP is a composite of discounts and premiums, which are variable nationally.

Estimating milk production is important in forecasting Class III milk prices and it must be remembered that Class III milk price is driven largely by the price of cheese, though other factors still play into the price determination of Class III milk. This is because Class III milk is the main component of cheese production. According to Davis et al., (2011), “cheese production absorbed 65% of the 127 pounds of milk entering the manufactured product production in 2008” (Pg. 260).

Bailey (2009) found that in forecasting the milk supply it is essential to estimate cow numbers, taking into account income, feed costs, slaughter cow prices, and seasonality trends. Previous research in this area indicates the necessity in analyzing cow inventories in terms of replacement heifer rates and milk cow slaughter rates. Using regional data from 1996 to 2001, Jesse and Schuelke (2002) developed a forecast model that outlines the relationship between milk production per cow and cow inventories and how these two factors determine the total milk supply. The authors point out that cow inventories do not demonstrate the same linear pattern historically, as seen in milk yield per cow.

Section 2.1.1: Construction of Dairy Forecasting Models

Multiple forecasting models have been developed to forecast various aspects of the cheese market. In response to recent availability of dairy products on the Chicago Mercantile Exchange (CME), Jesse and Schuelke (2002) constructed a basic forecasting model of Class III and Class IV milk prices. Specifically, the industry was divided into four product allocations: butter, cheese, whey, and non-fat dry milk. Using data from April 1997 to December 2001 they estimated the USDA’s National Agricultural Statistical Service (NASS) cheddar cheese price using an Ordinary Least Squares (OLS) regression. They found that cheddar cheese price, a product of Class III milk, is a function of per capita income and total supply with seasonality influences. The cheddar cheese price regression is the poorest fit compared to the three other dairy product price models developed in the research, but the estimates of the coefficients are correct. Simplistic models such as these allow industry participants to see the effects milk production and consumption have on the price of Class III milk (Jesse and Schuelke, 2002).

Mosheim (2012) forecasted use and price variables for the dairy sector by constructing six forecasting model: OLS; two-stage least squares (2SLS); three-stage least squares (3SLS); seemingly unrelated regression (SURE); restricted vector autoregression (VAR); and unconstrained vector autoregression (VARX). Using quarterly data beginning fourth quarter 1998 through the first quarter 2009, they forecasted variables pertinent to the dairy industry, including milk price, using an ex-post forecast through the first quarter in 2010. The author concluded that the unconstrained vector autoregressive model with exogenous variables tends to forecast prices and the number of cows better, in terms of accuracy and prediction correctness, than the other models. Although VARX outperformed all other models in terms of price forecasts, it does not predict items well for farm supply and commodity balance sheets.

In 2006, Schmit and Kaiser forecasted fluid milk and cheese demand for the next decade using a partial equilibrium model of the U.S. dairy sector with time-series data from 1997 to 2005, via an ex-post method. They modeled the industry using three marketing levels: retail, wholesale and farm. The wholesale market level was further separated into three categories: fluid, cheese and other manufactured dairy products. The Class III milk price is paid by wholesalers to the milk producers for milk to be used in cheese processing. Additionally, population demographics according to age and race are incorporated into the modeling framework (Schmit and Kaiser, 2006).

A partial equilibrium model of the dairy industry was created by Liu, et al. (1990). This model reflected the dairy industry in three different marketing levels including farm, wholesale/processing, and retail. The retail and wholesale/processing levels were further divided into the manufacturing sector of the dairy industry and the fluid market. These levels of the market were constructed to show the impact of advertising on the different levels of the market price. The system of equations was composed of demand and supply relationships which had prices and quantities endogenous to the model with vectors of supply and demand shifters as the exogenous variables allowing for the estimation of the over-identified equations. This model construction, along with Schmit and Kaiser's (2006) model, will be used to specify the system of equations used in this research.

Section 2.1.2: Additional Factors within Forecasting Models

Feed costs and income play an important role in the dairy industry. Bailey (2009) indicated that feed costs and income share a relationship that is quantified by milk revenue less feed costs. This financial variable will be approached in regards to the different roles feed costs and milk profit play in determining cow inventories and milk production per cow. Feed costs and revenue will be addressed using a different methodology from the research conducted by Bailey (2009); this will be discussed in chapter three. Mosheim (2012) also indicated that the cow inventories of today must account for the cow inventories in previous time periods, meaning they are autoregressive. An autoregressive component is necessary in the forecasting models for price forecasting because the construction of the models is an attempt to improve upon the rational expectation that the value of yesterday is equal to the value of today. Rational and also adaptive expectation assumptions can be extended to say that the value of yesterday is influential on the value of today.

An essential consideration is the use of quarterly or monthly data. According to Mosheim (2012), the quarterly time frame is capable of capturing the implicit seasonality of the sector and minimizes the volatility, which will often occur with monthly data along with decreasing the chances of autocorrelation of the error term. However, the quarterly model is limited in the degrees of freedom, thus its ability to specify and estimate the model and autocorrelation associated with monthly data can be addressed through autoregressive terms. Additionally, using monthly data allows the model to quantify the seasonality and volatility that actually occurs with the Class III milk price.

There is a need to address the need for monthly seasonality within a dairy forecasting model because the trends of each individual month are unique and can be lost in an averaging of quarterly or annual data. Research suggests that milk production varies throughout the year and is highest in the spring and lowest in the fall and this variance in production can cause problems for processors in the industry (Sun, Kaiser, and Forker, 1995). Not accounting for seasonality would neglect a defining characteristic of the dynamics in the dairy industry and fail to fully describe and forecast volatility in the market (Bailey, 2009). Seasonality is also seen within previous hedging research. Wang and Tomek (2005) indicate that prices in certain months will exhibit different variance and may be more skewed than other months in terms of risk management practices.

Section 2.1.3: Hedging Analysis and Risk Management

Hedging strategies are numerous, but a vital component is to determine how commodities are related to the futures market, thus allowing market participants to utilize the futures market as a risk management tool. Literature indicates that non-storable commodities are typically not forecasted well by their respective futures market, and that the futures market plays a larger role in forward pricing (Tomek and Gray, 2005). This suggests that the prices are not absorbing all of the relevant information available (Fama, 1970). Milk and other dairy products are considered non-storable commodities and as such there is an inefficiency occurring in the market, though cheese is a semi-storable dairy product and quality is not degraded if stored for short periods of time (Tunick et al., 1991).

Koontz, Hudson, and Hughes (1992) modeled the efficiency, meaning the ability of the futures contract price to reflect feed costs, during the contract life of non-storable commodities, such as hogs and cattle. Their research indicates that early in the contract life feed cost is a major determinant of the range at which a contract trades and then closer to contract maturity futures prices will adjust to the prevailing market conditions. Conclusions were made that as the delivery month approached, the relationship between feed costs and futures prices deteriorated to reflect the market conditions. During the delivery month, the variance was the largest, indicating that the delivery month is the hardest to predict. This will prove valuable to producers as they learn how the futures price is related to their costs of production and determine their hedging horizon based on their operations; meaning they will determine when to hedge their position based on their financial environments and the conditions reflected in the futures market for Class III milk. Wang and Tomek (2005) indicate that routine hedging will allow producers to reduce the variance of their returns and lock in the "average" returns.

2.2 Dairy Market Dynamics and Milk Pricing

Dairy market composition is an array of multiple pathways through which raw milk is transferred from the farm to the consumer. Milk can be consumed in its fluid state or processed into other goods like cheese, butter, dry-milk, ice-cream, yogurt, etc. A basic supply chain of the dairy industry can be seen in Figure 2.1.

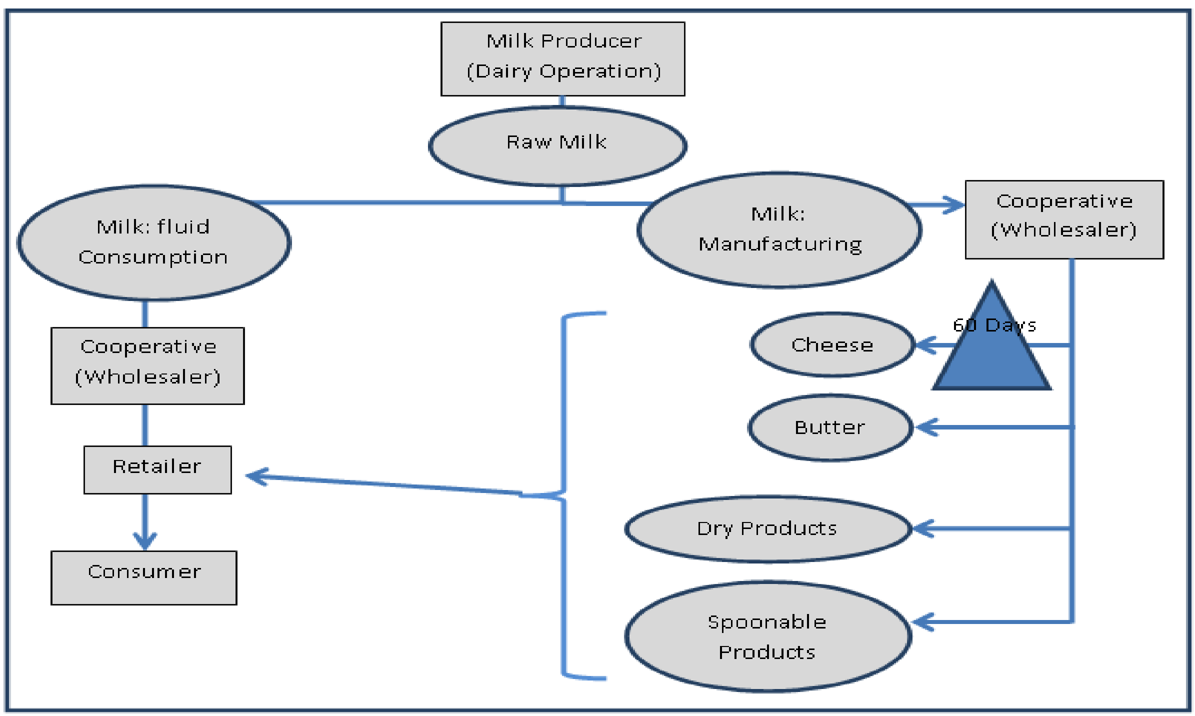

Figure 2.1. Dairy supply chain for the market in the United States

As shown in Figure 2.1, milk moves from the raw state on the farm to fluid consumption or the manufacturing sector. Raw milk designated for fluid consumption is pasteurized by the wholesaler (often a cooperative) and then sold to the retailer and consumer;

this is considered Class I Milk. Within the processing and manufacturing sector of the industry three classes of milk are utilized. The classes of milk are not a representation of milk quality, rather the price paid by the processor based on the purpose of the milk; milk classes are described in Table 2.1 (Jesse and Cropp, 2003).

Table 2.1. Milk classifications, description, pricing formulas for the dairy industry

Milk Classification	Description	Pricing Formula
Class I	Fluid Milk	= 0.965 × Class I Skim Milk Price + 3.5 × Class I Butterfat Price
Class II	Soft Manufactured Products	= 0.965 × Class II Advanced Skim Milk Price + 3.5 × Class II Butterfat Price
Class III	Cream Cheese and Hard Cheeses	= 9.64 × NASS cheese Price + 0.42 × NASS Butter Price + 5.86 × NASS Dry Whey Price – 2.57
Class IV	Butter and Dry Milk Products	= 4.20 × NASS Butter Price + 8.60 × NASS Nonfat Dry Milk Price – 1.69

The ability to process milk into these different products has incited the industry to create pricing systems as a reflection of the requirements for each product, instead of pricing system based solely on milk components. These pricing systems are based on the pounds of milk needed to create one pound of each good, and the milk component percentages of fat and protein. As a relevant example for the cheese markets, the Van Slyke formula states that for one pound of cheddar cheese the requirements are ten pounds of milk with 3.76 percent milk fat (Stewart and Blayney, 2011). A component based pricing system is easily convoluted because each individual load of milk will vary based on components and the designated usage.

In result of the complications of a component pricing structure, the milk classification system was created to price milk based on usage. The price classification system has been formulated into a price which producers receive; this producer price is referred to as pooling.

Pooling, as defined by Jesse and Cropp (2003), "is when producers receive a uniform price for their milk or milk components regardless of how their milk is used" (p.15). The pooled price is referred to as the All Milk Price (AMP).

AMP is a weighted average of the price of milk for fluid consumption and the price of milk for manufacturing. This formula can be described as using the prices determined by the classification system to average the price paid to the producer with deductions incorporated into the formulation. These deductions are concerned with milk components (protein, butterfat, solids, and somatic cell counts) and with the producer's location relative to markets. AMP is variable across the country because where the milk is produced relative to the market will influence the price producers receive (Figure 2.2). For example, producers in Idaho will receive a lower premium (or even a discount) compared to producers in New York who are closer to major population centers. AMP will change from region to region and when running a national level model it would be wrong to assume that all producers are receiving the AMP.

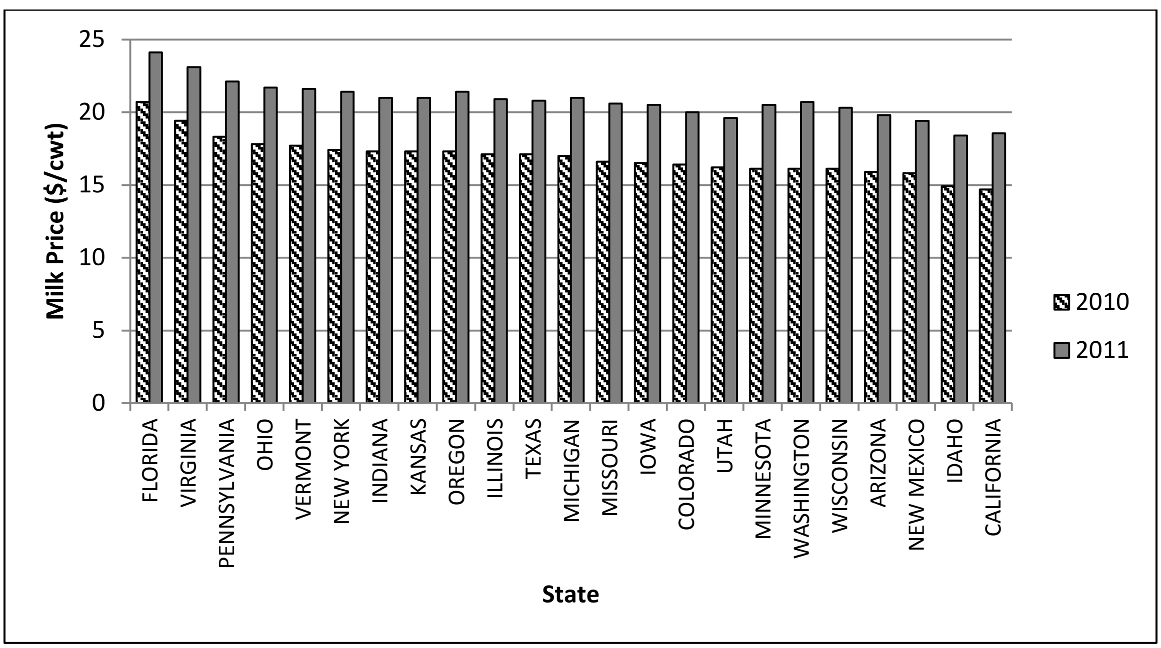

Figure 2.2. Milk price differences as they vary by state from 2010-2011

To account for this price difference which occurs on a national level, it is more accurate to assume producers receive a price dependent on the price classification system. In the case for most producers, the assumption is made that their profit is primarily determined by changes in the Class III milk price. This is more accurate because it is assumed Class III is a minimum price producers would receive, preventing an overestimation of the revenue received from milk production. This price, Class III milk, will be referred to as farm price. The correlation coefficient between AMP and Class III milk price indicates these two variables are highly correlated, more so than other milk price classes (Table 2.2), because of this Class III milk price can easily be used in place of AMP (Mosheim, 2012).

Table 2.2. Correlations of milk classification system and the national All Milk Price

	All Milk Price	Class I	Class II	Class III	Class IV
All Milk Price	1.0000				
Class I	0.9545	1.0000			
Class II	0.9360	0.8906	1.0000		
Class III	0.9651	0.8971	0.8465	1.0000	
Class IV	0.9225	0.8612	0.9749	0.8438	1.0000

Figure 2.3 shows how Class III milk price moves with the national AMP across time. The movement seen in Class III milk price and AMP is an illustration of the correlation which is known to occur within the dynamics of the dairy market as indicated in the previous table. The conclusions about correlation are a major driver to the majority of this research. Now, that this has been discussed in addition to how prices are formulated within the market, the remainder of this chapter will deal with Class III milk prices and its related factors.

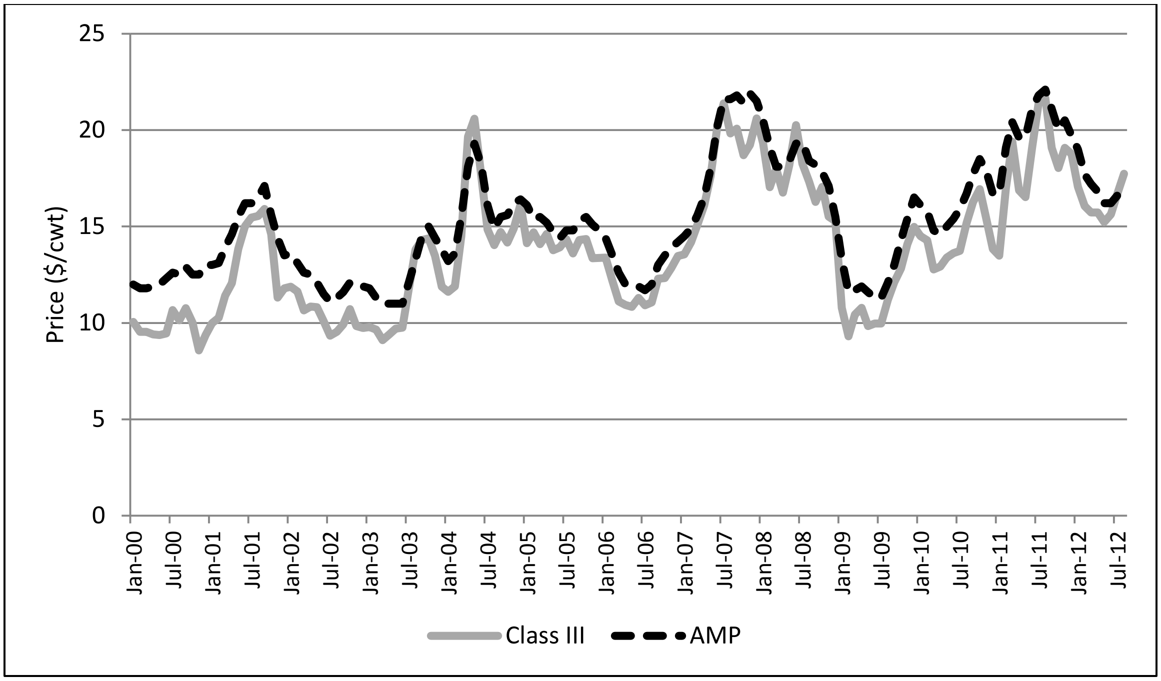

Figure 2.3. Graph of the correlation between All Milk Price and Class III milk price

2.3 Interactions within the Supply Chain

Class III milk goes through many stages between the producer and consumer as it is transferred from various levels in the industry and processed from a raw good into final products. Because hard cheeses and cream cheese are the main products of Class III milk, the assumption that cheese price is the most correlated with AMP, as with Class III milk price, can be made. This implies the cheese market will be the most important indicator of Class III milk prices as it moves past the wholesalers and retailers and then consumers. To track Class III milk price through the cheese market, Stewart and Blayney (2011) indicate the process of transforming milk to cheese is approximately 60 days or more for aging. Additionally, the cheese has to be further processed by cutting, shredding, wrapping and further handling. Cheese is then able to be stored for extended periods of time, with little effect seen on the palatability of the product (Tunick et al., 1991).

The wholesaler in the dairy market serves as the middleman to the industry, by processing the raw good into a product for the retailer. Wholesalers are often cooperatives like Land O'Lakes or Dairy Farmers of America (DFA). However, wholesalers can also be distributing and supply plants, along with the standard cooperatives (Jesse and Cropp, 2003). In this thesis, participants in this level of the market will be referred to as wholesalers.

As part of their role in the industry wholesalers can potentially pay the AMP to producers, but as part of the national analysis it is assumed they pay the Class III price to producers. Wholesalers process and manufacture products like butter, cheese, yogurt, dry milk, etc. These products all have individual prices marketed to the retailer. Typically the price charged to the retailer is the price of the particular component plus some 'up-charge'.[1] The price paid by the retailer to the wholesaler is called the wholesale price (P_w).

An example of the wholesaler's role can be seen with a fictional company, called Company A. Company A is a producer of Italian products like calzones and pizza. As part of production of pizza and other cheese related products, they contract with various wholesalers, such as Leprino and DFA, for their cheese supply. The price Company A will pay for the cheese is the Class III milk price (on a per lb. price) in addition to some up-charge associated with processing and transportation. To calculate the price per lb. of cheese paid by Company A to the wholesaler the price per lb. of milk is multiplied by 10 because cheese manufacturing requires approximately 10 pounds of milk per 1 lb. of cheese.

$$(1) \qquad \textit{Cheese price paid by Company A (\$/lb.)} = \frac{\textit{Class III milk price/cwt.}}{\textit{100 lbs.}} * \frac{\textit{10 lbs. of milk}}{\textit{1 lb. of cheese}} + upcharge$$

[1] An up-charge is similar to a basis price though it differs; it includes transportation, manufacturing, and storage costs into the price formulations along with the cost of processing fluid milk into various cheese varieties.

This calculation of the Class III price on a per lb. of cheese produced is in addition to the up-charge determined by the wholesaler, which is dependent on the location of Company A to the processing plant and the type of cheese produced for Company A.

After milk has been transferred from the producer to the wholesaler it is then sold to the retailer. The retailer will pay a price similar to the price paid by Company A, as discussed above. Retailers will then turn around and sell the dairy manufactured products at retail prices (as seen at the grocery store). This is referred to as the retail price (P_r); this is the average retail price of cheese provided by the Agricultural Marketing Service (AMS).

Previous discussion has indicated the importance of Class III milk prices to the industry. Class III milk price serves as the primary driver to the AMP and is usually the minimum price for which producers will be paid for their milk, ignoring the possibility for deductions due to lower quality milk. Class III milk price continues to be a major player for cheese manufacturing and retail. The remainder of this study will be concerned with the forecasting of Class III milk prices, to serve as a risk management tool for the industry.

2.4 Class III Milk Price and Volatility

Balancing acts occur daily within dairy markets as producers, wholesalers and retailers juggle the volatility which occurs between supply and demand equilibriums. Milk production is a unique industry where the capacity of the market is limited and can be exceeded by the milk supplied. In addition, the quantity of milk supplied can only be changed significantly in the long run. Thus, it is observed when there is oversupply of milk it will take time for the market to adjust. Cooperatives must manage the balancing between fluid milk consumption and milk used for processing based on the demand of the retailers. Problems occur within the dairy markets when the supply of the milk from the dairy producers exceeds the demand of the retailer or even the capacity of the cooperatives, causing severe price fluctuations.

Severe price fluctuations are referred to frequently as the price volatility of milk and have grown to be a primary concern for many producers. Research cautions that dairy market prices should not neglect the unexpected aspect of volatility. Curley (2010) indicates that some movement in pricing is good for any industry. The price movement is good for the industry because it allows the market to adjust to changes in both the supply and demand, using price as a tool. However, the problem arises when the movement in pricing is unanticipated. Caution needs to be taken to not confuse volatile prices with undesirable prices (Curley, 2010). Figure 2.4 displays Class III milk prices since 2000. Changes in prices over this time period are observed and some of these changes were expected, though undesirable. However, there is an element of volatility which occurred over this time period.

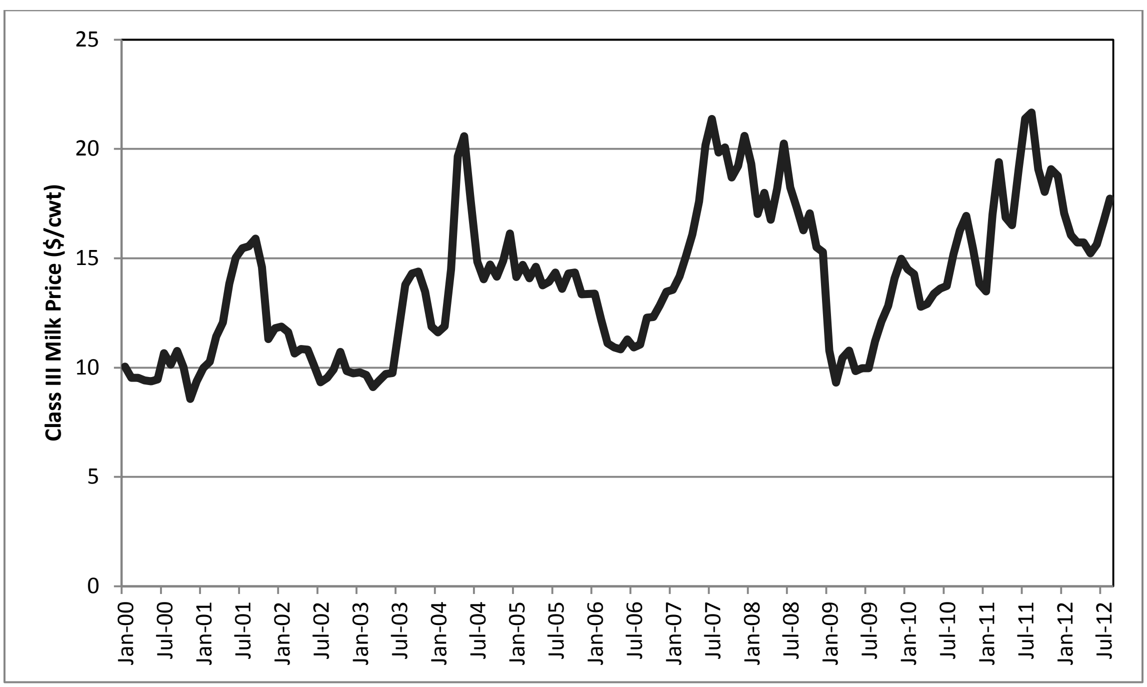

Figure 2.4. Historical Class III milk prices from 2000-2012

Historical volatility can be used to measure the volatility which has occurred over a specified period in the past and is calculated as follows:

(2) $$\textbf{Historical Volatility} = \boldsymbol{\sigma}(\boldsymbol{P_t^s})$$

(3) $$\boldsymbol{P^s} = \frac{\boldsymbol{P_{Current\ Month}} - \boldsymbol{P_{Previous\ Month}}}{\boldsymbol{P_{Previous\ Month}}}.$$

The standardized price (P^s) is calculated using the percentage change month over month of the Class III milk price. The time, *t*, over which the standard deviation (σ) is calculated is equal to two months as a reflection of the volatility which occurs on a monthly basis in the dairy milk market from January 2000 to July 2012. Figure 2.5 shows the historical Class III milk price volatility producers have experience.

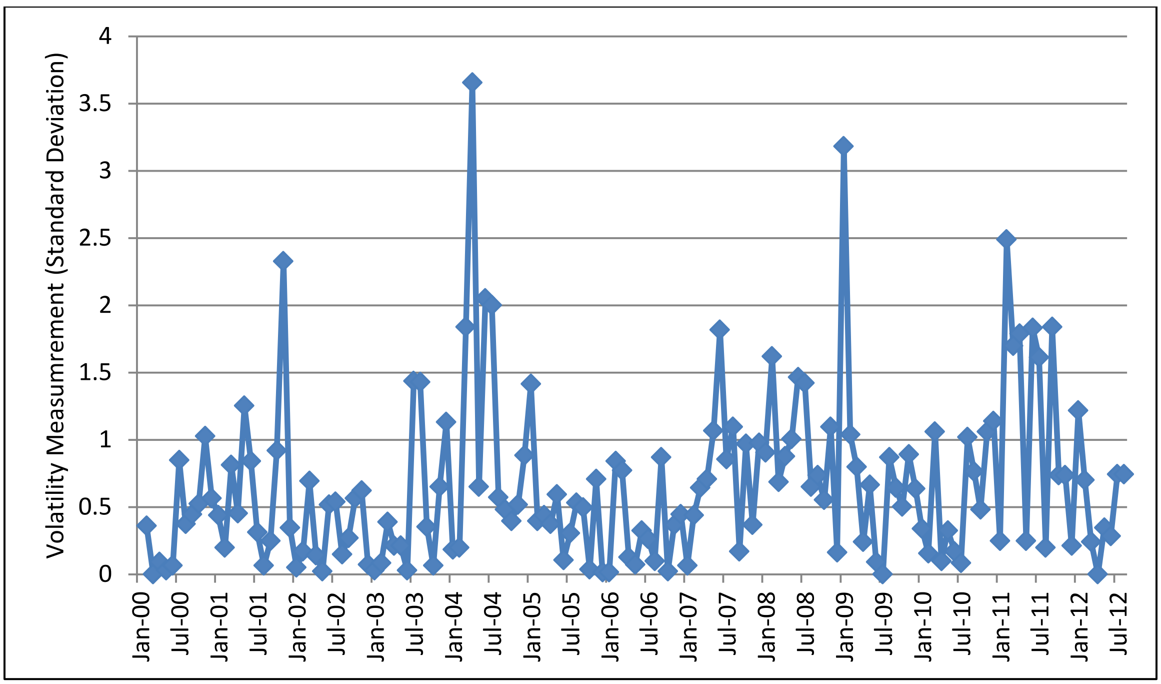

Figure 2.5. Historical volatility of monthly Class III milk prices, 2000-2012

Section 2.4.1: Factors Influencing the Supply of Milk

Numerous reasons exist for the excess supply of milk in the dairy market; however, there exist two main factors: (1) milk cow inventories and (2) milk production per cow. The management of cow inventories and production per cow will affect the total milk production. As a result, factors which cause changes in cow inventories and production per cow will eventually change the supply of milk and ultimately affect the price received by producers.

Milk cow inventories are influenced by the slaughter cow numbers within the United States, the number of replacement heifers, feed costs and revenues (or overall profit), seasonality, and a linear trend. One assumption that can be made is the milk price received at the farm level will affect the milk cow inventories. Figure 2.3 illustrates as Class III milk price increases (decreases), the U.S. milk cow inventory will increase (decrease) in the following months.

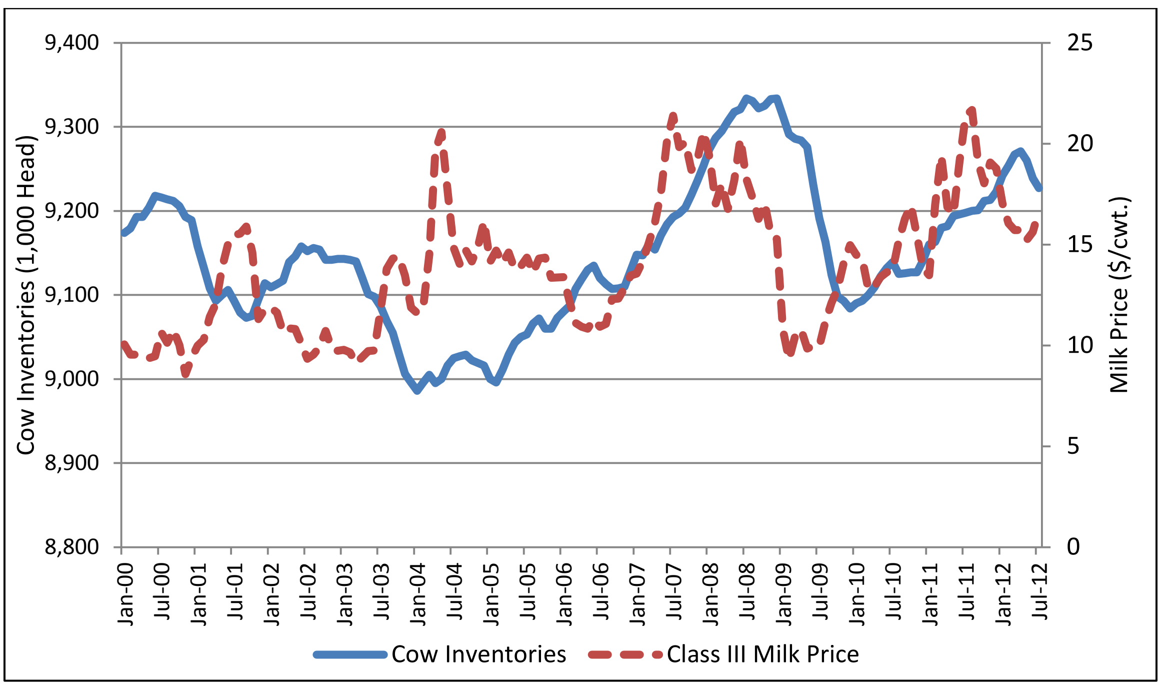

Figure 2.6. Historical Class III milk prices and U.S. milk cow inventory, 2000-2012

Feed cost will have an impact on milk cow inventories because this is the largest expense to producers (USDA-ERS, 2012). In 2011 feed costs were approximately 80% of a producer's total costs. This also plays a role when considering milk production per cow. As feed costs increase, it can be hypothesized a producer will feed the cow slightly less or adjust to cheaper and lower quality feed to save on the margin.[2] However, in the long run we will see that as feed costs remain high then milk production per cow will increase. This phenomenon is due to changes in efficiency. As feed costs increase, cow inventories will be diminished by removing the least productive cows from the herd first, resulting in the high producing cows remaining in the herd and improving herd efficiency. Milk production per cow will then increase as cow inventories decrease (Figure 2.7).

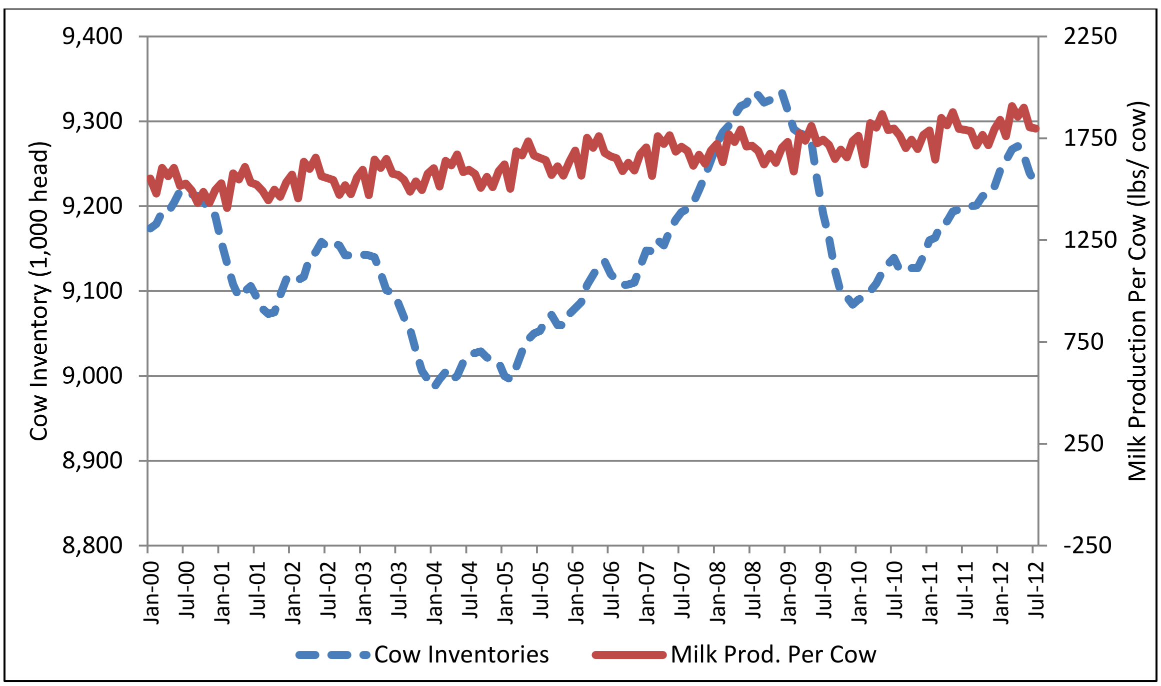

Figure 2.7. Historical milk production per cow and cow inventories, 2000-2012

[2] The margin refers to the difference between the revenue generated per cow minus the cost incurred by the individual cow.

Section 2.4.2: Feed Costs and Revenues

Feed cost calculations assume the average cow in the United States is fed a uniform ration consisting of some combinations of protein, fats, and carbohydrates which are provided in the form of a variety of feedstuffs. The Agricultural Reform, Food and Jobs Act (ARFJA) ration was suggested to the proposed Farm Bill 2012 as a calculation of overall feed cost per cow in the United States, with additional pounds of feed included to represent an overall cost per cow per day. The ARFJA is a 16% protein dairy ration that was proposed as part of the margin insurance program for dairy producers in the 2012 Farm Bill (Gould, 2012). This ration assumes that an average cow producing milk will consume approximately 102.5 pounds of feed per day with 58.4% corn, 14.4% soybean meal and 26.8% alfalfa hay, as seen in Equation 4.

$$(4) \qquad \boldsymbol{Feed\ Cost_{1}}(\$/\boldsymbol{cow/day}) = \mathbf{60.1}\ \frac{\boldsymbol{Corn}\ \$/\boldsymbol{bu}}{\mathbf{56}\ \boldsymbol{lbs./bu}} + \mathbf{14.7}\frac{\boldsymbol{SBM}\ \$/\boldsymbol{ton}}{\mathbf{2000}\ \boldsymbol{lbs./ton}} + \mathbf{27.4}\frac{\boldsymbol{Alfalfa\ Hay}\ \$/\boldsymbol{ton}}{\mathbf{2000}\ \boldsymbol{lbs./ton}}$$

It is clear that this ration formulation is not a realistic choice for dairy rations because on a dry matter basis, this ration is above the realistic daily feed consumption per cow; as a result another ration formulation was calculated with 52 lbs. of feed on as fed basis using the program maintained by Robinson (2005). This ration is represented in the following equation:

$$(5) \qquad \boldsymbol{Feed\ Cost_{2}}(\$/\boldsymbol{cow/day}) = \mathbf{7.88}\ \frac{\boldsymbol{Corn}\ \$/\boldsymbol{bu}}{\mathbf{56}\ \boldsymbol{lbs./bu}} + \mathbf{7.73}\frac{\boldsymbol{SBM}\ \$/\boldsymbol{ton}}{\mathbf{2000}\ \boldsymbol{lbs./ton}} + \mathbf{36.45}\frac{\boldsymbol{Alfalfa\ Hay}\ \$/\boldsymbol{ton}}{\mathbf{2000}\ \boldsymbol{lbs./ton}}$$

The ration formulations will estimate the amount spent exclusively on feed per cow per day. As part of the ration formulation, prices of three feed inputs have been incorporated.

These prices are subject to change due to market conditions and have been variable over time. Consequently, as the prices of feed inputs change the overall feed cost per cow per day will also change. These two feed cost estimations have a correlation coefficient of 0.9872.

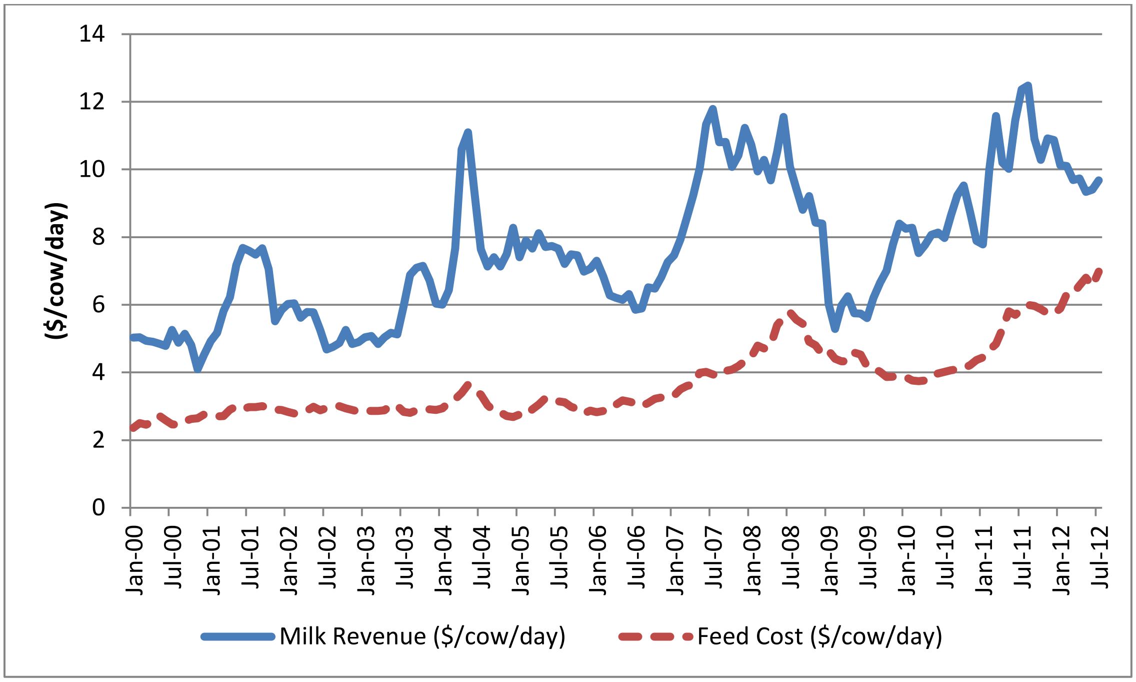

Figure 2.8. Historical feed costs and milk revenues based on the Robinson dairy ration

The information contained in the feed cost estimation is valuable when looking at the dairy market because feed costs can have significant impacts on milk production. Additionally, the Class III milk price producers receive must also be observed in relationship to the cost of feed. This can be calculated by creating a variable of total revenue per cow per day:

(6) $$\boldsymbol{Total\ Revenue}(\$/\boldsymbol{Cow}/\boldsymbol{Day}) = \frac{\boldsymbol{Total\ Milk\ Produced\ Per\ Cow\ Per\ Day}}{\boldsymbol{100\ pounds\ of\ milk}} \times \frac{\boldsymbol{Class\ III\ Milk\ Price}}{\boldsymbol{cwt}}.$$

Although total revenue per cow per day has increased across time, Figure 2.8 illustrates it is failing to keep pace with increases in feed cost per day. Revenue per cow addresses the issue of a dairy farmer's profit when used in conjunction with feed cost per cow. Milk profit is calculated as follows:

(7) $$Milk\ Profit\ (\$/cow/day) = Revenue(\$/cow/day) - Ration\ Feed\ Cost\ (\$/cow/day).$$

Section 2.4.3: Factors Influencing the Demand of Milk

Demand conditions within the dairy market also affect the price volatility of milk. One factor influencing demand is the per capita consumption of dairy products. Over the past twenty years per capita consumption of fluid milk has declined, with many sources citing the failure of the industry to adapt to the changing market and compete with other beverages. Declining fluid milk consumption is contrasted with a second trend of increasing per capita consumption of cheese, a product from Class III milk (Hoskin, 2012).

Rising cheese consumption has been a result of a variety of reasons including improvements in the convenience, availability and health benefits of the product. Davis et al., (2011) found the following factors have contributed to the increase in cheese consumption:

(1) Increased availability of cheese varieties;

(2) Expanded cheese use by fast food and pizza restaurants;

(3) Expanded cheese use as an ingredient by both food manufacturers and home cooks;

(4) Changes in consumer demographics; and

(5) Increased consumption of "cheese-rich" ethnic foods (Manchester & Blayney, 1997).

It may be noted that consumption is not a true measure of demand. To further the conversation concerning changing demand conditions and the effect it has on volatility of milk price, international dairy markets will be examined. Exports of U.S. dairy products have led to an increased presence in the global dairy markets and an increase in demand for certain dairy products.

Recent advancements in the market of whey products has led to an increasing demand for U.S. whey exports as producers of bakery and other processed foods have seen the opportunity to incorporate whey into their products with the technology advancements (Dairy Policy Analysis Alliance, 2010). Cheese export markets have also established a greater influence in the global market, fueled by the growing development of pizza and fast food chains in markets in Asia and Oceania.

This demand by food companies for cheese, specifically pizza companies, has been on a steady climb since the early 1990s. Schmit and Kaiser (2006) found, using a demand-forecasting model, that per capita cheese consumption would continue its trend upward for the next 10 years with an average annual growth rate of 0.8%. According to the USDA's Foreign Agricultural Service (2011), U.S. cheese production was projected to expand in 2011 by 4.8 million tons (1% expansion) due to higher cheese prices.

This demand is a potential contributor to the higher cheese prices experienced in 2012. Strong export demand can be contributed to a number of factors. First, popular U.S. pizza chains have begun expansion into international markets, specifically Mexico, South America and Asia. Jerry McVety was quoted saying, "There are very viable new markets in certain countries, like in the Middle East, Brazil, Chile, all of Europe and Asia" (Walkup, Pg. 1).

Evidence of expansion into these viable markets is seen in Pizza Hut's launch of 4,770 pizzerias in 90 countries.

The growth of international food chains has led to an increase in demand for more products which would contribute to the production of pizza, Italian foods, and multiple other fast food items requiring cheese. These fast food chains are contracted with many cheese producers in the U.S. and the world, thus increasing demand for cheese varieties as the population expands to include more demographics and countries. The largest mozzarella producer in the U.S., Leprino Foods, has made a point of continuing to use U.S. milk for the production of their mozzarella instead of switching to international sources. Leprino Foods along with other wholesalers contribute to increases in milk demand at the farm level. This is seen in the recent opening of a Leprino processing plant in Greeley, Colorado which needs 60,000 more dairy cows in the area to meet the milk demands of the facility (Whaley, 2011).

A second factor influencing international market expansion is a focused effort on export assistance by some organizations to support dairy milk prices and supply. Cooperatives Working Together (CWT) has established an Export Assistance program which *"positively impacts producer milk prices in the short term by reducing inventories that overhang the market and depress cheese and butter prices. In the long-term… the program helps member cooperatives gain and maintain market share, thus expanding the demand for U.S. dairy products and the farm milk that produces them"* (Dairy Today Editors, Pg. 1). In 2012, CWT assisted member cooperatives with exporting the equivalent of 876 million pounds of cheese. This program has worked to improve the All Milk Price slightly, but the change is so small that the presence of CWT can be ignored with market analysis. Figure 2.9 illustrates that export assistance does have some presence, but it is not large.

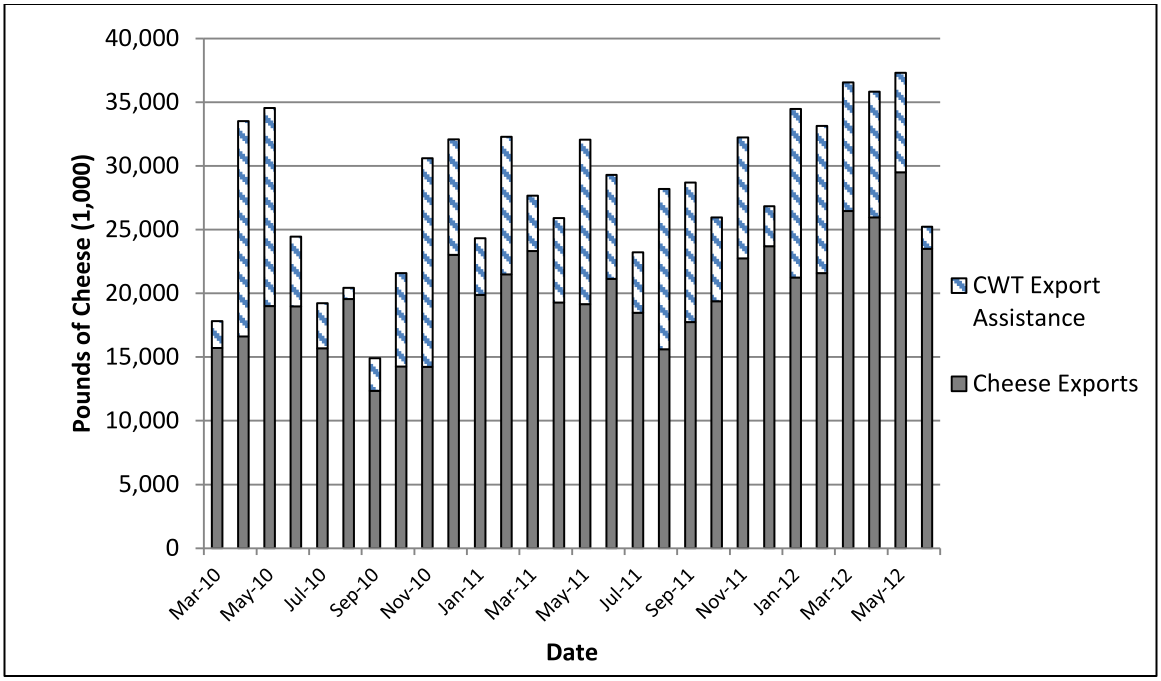

Figure 2.9. Cheese exports from the U.S. and CWT Export Assistance of cheese

An analysis for CWT indicates that the AMP has been supported only slightly in the past few years since the program truly took off. Results from 2007 indicate the effect on price was $0.20 per hundredweight, but has fallen to $0.04 per hundredweight in 2009 and was then $0.13 per hundredweight in 2011 (Brown, 2011). Programs in the past similar to this were managed by the government, like the Commodity Credit Corporation (CCC), however the impact on milk price was only slight and the program has not been used frequently since 2000, with net removals only occurring between 2002-2003 and 2008-2009 (USDA-FSA, 2010).

Section 2.4.4: Summary of Supply and Demand Influences

Interactions between fluctuating supply and demand conditions have led many producers to expect volatile milk prices. In these markets, prices are often in favor of the retailer and cooperative. With many producers not experiencing the price increases received by the retailer until weeks or months later, if at all. The volatility in prices producers experience should encourage risk management; however, little risk mitigation occurs within dairy markets.

Rising costs of production throughout the livestock industry have caused great concern over the availability and affordability of food products for human consumption in the coming year. Projections for the coming year show that food prices will increase between 3 and 4 percent as result of the record drought experienced through the Corn Belt the summer of 2012 (Nixon, 2012). Dairy products are expected to increase between 3½ to 4½ percent in 2013 (USDA-ERS, 2012). Class III Milk Prices will be influenced by the price increases expected for dairy products derived from this milk classification, such as cheese.

Along with output price changes, producers will be faced with an increase in input costs as the price of feed increases. The drought has caused great concern for dairy farmers because the difference between revenue per cow and cost per cow has decreased rapidly and in some cases has become negative. Reports by the USDA indicate that dairy cow slaughter has turned upwards because the record heat has caused a reduction in milk per cow. USDA estimates for milk production indicate a year-over-year decline (Johnson, 2012). Producers will only be able to survive on negative margins in the short run, and the input prices experienced this summer will continue to affect the supply chain in terms of cow inventories and milk production per cow into the coming year.

Section 2.4.5: Risk Management among Dairy Producers

Risk management is the accumulation of logical practices chosen to manage and minimize the risk of an organization, in this case a dairy operation or other participants in the market. Many tools exist to manage risk and maximize returns in the long-run. One study indicates that risk in the dairy market is best managed in two main ways: the utilization of tools such as futures, forwards, options markets, and/or public policy decisions (Curley, 2010). Within the dairy industry opportunities to manage risk are rarely employed outside of the public policy realm. Meaning the opportunity to use futures trading as a hedging opportunity remains underutilized by many participants in the dairy industry.

Trading volume in dairy markets is in the low hundreds of futures contracts per day in the nearby months, whereas other livestock such as lean hogs and live cattle markets are in the thousands of contracts per day in nearby months. Low volume trading, thin markets, allows relatively few players in the industry to make large impacts on pricing for the entire industry, for promotion of their own self-interest (Curley, 2010). Ultimately smaller players in the dairy market are hurt as many industry participants choose to ignore these risk management tools.

Via pricing strategy tools, farms and companies make decisions on their own terms according to their preference in management of prices and input expenses. When futures and forwards contracts are utilized a market participant can lock in a margin and/or lock in the prices of their inputs or outputs. These strategies allow producers and companies participating in the cheese and Class III milk markets to manage the risk associated with these commodities. Development of price forecasts gives market participants the opportunity to make risk management strategies at a cost, but that eventually becomes a value to the producer (Drye and Cropp, 2001).

2.5 Contributions to the Literature

Dairy product price forecasting models are often concerned with forecasting the price of specific dairy products. However, this approach tends to ignore the fact that many dairy producers are paid on a Class III milk price basis and that NASS prices for cheese are only concerned with cheddar. Broadening the scope of the model to look at forecasts of Class III milk price will allow multiple participants in the industry to use the model for both Class III milk price and also different cheese types.

Foundational characteristics of the model such as cow inventories and milk production per cow have been concerned with the explanatory power of the feed cost variable or a marginal profit calculation between milk revenue and feed cost. This research will investigate the impact of a cumulative profit variable and its ability to explain milk cow inventories and production per cow. This cumulative profit variable is an addition to the literature, which has previously only discussed profit margin or feed costs. The cumulative profit will allow future research to understand the fundamental difference for how producers make decisions. This will indicate that producers base decisions on longer term profits and losses which are cumulative from period to period, instead of the previously asserted theory that profits or costs from this time period or previous time periods are determinants of producer decisions.

An additional contribution to the literature is the use of models which are simplistic in their construction with minimum variables included but still maintaining the ability to forecast. Previously, many models focused on multiple variables for their forecasting potential, but as a result the models were complicated and often filled with variables that could have been excluded. As a result of this observation it was decided that the models created in this thesis would attempt to simplify previous work, by using fewer variables in the model construction.

The final contribution to the literature is by adapting work by Koontz, Hudson, and Hughes (1992) in observing the relationship feed costs or profit margins share with future contract prices and at what point this relationship deteriorates to reflect current market conditions. This section of the research will allow producers and other market participants to determine the point at which the future contract prices for Class III milk will reflect their revenues and at what point prevailing market conditions will have a more significant influence, so they can adjust their risk management accordingly.

CHAPTER 3: METHODOLOGY

Class III price forecasting models will be constructed with the foundations of the models grounded in the dynamics of the dairy industry. The objective of the methodology is to model accurately the interactions that occur within the market and ultimately influence price. As an initial step the data incorporated into the model will be tested for stationarity to decrease the chances of feed-back interactions occurring with non-stationary data. To reflect the dynamics of the dairy market all foundational models will be founded on the same assumptions regarding milk production, essentially that milk cow inventories and milk production per cow are the main influences on total milk production. The methodology will continue by outlining the six models in Section 3.4 through Section 3.7. This chapter will conclude with discussion concerning the model comparisons (Section 3.8) and the hedging analysis (Section 3.9).

3.1 Data Testing

Before estimating a forecasting model, further examination of the data is required. First, one must test for stationarity, which implies testing the mean and variance to see if they change across time. All data used within the model are tested for stationarity with the commonly used Augmented Dickey Fuller (ADF) test. As with most economic time series data, it is likely prices and quantities are a random walk and so we must take the first difference if the ADF suggests non-stationary data. The exception to the random walk characteristic is biological data. Biological data is a deterministic trend and un-stochastic in distribution. As a result, the biological data (i.e., milk production per cow) used in this research will not be first differenced. The lag length which influences the stationarity of the data is critical to determine for the construction of the forecasting model because it is important to know at what lag the data will interact.

The ADF is used to test for stationarity and correct for correlation within the error term and is as follows:

$$(8) \qquad \Delta X_t = \delta X_{t-1} + \mu_t.$$

X_t represents the various independent variables that will be used in the forecasting models. To look for stationarity we must regress them against the lagged values of themselves, X_{t-1}, in addition to an error term, μ_t. Delta, δ, is what the hypothesis test of the ADF test is scrutinizing. The null hypothesis states that if delta is equal to zero then there exists a unit root and the variable is non-stationary. The alternative hypothesis is that delta is greater than zero, meaning the time series is stationary. Ultimately, this test looks for a relationship between the error terms and the independent time-series variable (Gujarati and Porter, 2009).

An additional test for each model is to examine if the models have an autoregressive nature, and to determine how far back the model should reach. Meaning, how far in the past can those prices influence today's price for cheese or milk production.

$$(9) \qquad Y_t = A_1 Y_{t-1} + A_2 Y_{t-2} \ldots . A_n Y_{t-n}$$

Y_t now represents the dependent variable within a model and the lags, Y_{t-1}, are the values of the dependent variable at previous times in the past through n periods. This test looks for a relationship between the current value of the dependent variable and past values of itself. For models representing the dairy industry looking for an autoregressive nature is a reasonable conjecture because it is likely the previous values of the dependent variable are influential on the current observation of the dependent variable. For example, it would be logical to conclude that the cow inventories of last month have some effect on the cow inventory of today. This is also a means to correct for correlation, which can be indicated by the Durbin-Watson statistic. The necessity of an autoregressive term will be determined based on the Durbin-Watson statistic before a lagged dependent variable is included in the model.

3.2 Model Foundations

The conceptual model in this study is a direct result of creating estimable equations of total milk production. This is based on the concept that total milk production contributes significantly to the pounds of milk diverted to Class III milk and ultimately the production of cheese and cheese prices. When national milk production is forecasted via regression analysis, two variables must be known, milk production per cow and total cow inventories, as they are essential for forecasting total national milk production.

The purpose of this step is to incorporate the financial environment existing in the dairy industry within the models. It is assumed milk production per cow is a result of profitability because within the dairy industry as the profitability decreases, an increase in cull cow numbers occurs. Typically, a dairy operation will cull those cows with the lowest production. As a result, when profitability decreases herd averages of milk production per cow will increase and vice versa. Also, as profitability increases there will be a positive (increasing) impact on the milk cow inventory. The initial estimable equations are cow numbers and milk production per cow; these are the foundational models.

Section 3.2.1: Milk Cow Inventory Model

The model for the milking cow inventory is specified to reflect the dynamics occurring within the milk cow inventories in the United States. It was determined variables that are related to the movement in and out of the milk cow inventory were essential to modeling this aspect of the market. The two variables that quantify the fluctuation of cow inventories are the cull milk cow slaughter numbers and the replacement heifer inventories. Cull milk cow slaughter inventories measure the rate at which milk cows are sent to slaughter and the replacement heifer rate is the measure of the inventory of replacement heifers biannually (this data has been interpolated to provide monthly data). The variable representing feed cost will be tested to determine if the feed cost is a more powerful explanatory variable than profit or cumulative profit (Section 3.3). Additionally, the model will compare the two ration formulations. The milk cow inventory is:

(10) $$INV_t = \beta_0 + \beta_1 CULL_t + \beta_2 CULL_{t-1} + \beta_3 CULL_{t-2} + \beta_4 REP_{t-3} + \beta_5 FC_t + \beta_6 INV_{t-1} + \beta_7 Trend + \beta_8 D_i + \mu_t.$$

The monthly time period is represented by *t (for t = 0, 1, 2 …, n), i* denotes the month, *Trend* is the trend, and μ_t is the error term. A trend term is used to quantify the influence of time on the dependent variable; it essentially measures the trend occurring overtime and so it is used in all of the models to capture this change over time. *INV* represents the national milk cow inventory while *CULL* is the variable for the cull cow inventory at time *t*. Two lag lengths are incorporated into the model because the inventory of slaughter cows from two months ago has an impact on the inventory of milk cows today. *REP* denotes the replacement heifer variable at time *t-3*; this model functions under the assumption that replacement heifer inventories of three months ago influence the milk cow inventory of today. The lag length of three months is determined by a testing up approach of the model to determine at what lag the variable is statistically significant, economically correct, and a higher R-squared.

FC is the feed cost in the current period; this model will be compared against other models using different financial components, such as profit and cumulative profit over some specified time period, and using the two ration formulations. A lagged dependent variable is included to minimize the probability of the occurrence of serial correlation, making it an autoregressive model. D_i is a dummy variable associated with the monthly data; January is excluded to avoid the dummy variable trap.

Section 3.2.2: Milk Production per Cow Model

Milk production per cow is more seasonally affected than the cow inventory, thus it is important that the model incorporates a seasonal dummy into the specification. An additional factor is the effect of feed costs on milk production per cow, under the assumption that as feed costs increase, lower quality feeds will be fed to minimize costs and as a result milk yield per cow will decrease, and vice versa. The milk production per cow is specified in equation 11.

(11) $$MPC_t = \beta_0 + \beta_1 FC_t + \beta_2 Trend + \beta_3 D_i + \mu_t.$$

MPC specifies the milk production per cow in time *t* with the error term of μ. *FC* is representative of a feed cost variable which will be explained further in the Section 3.3. The seasonality that affects milk production per cow is captured by dummy variables, $D_{i,}$ with January being dropped.

The final step of these foundational models is to look at the overall total milk production for the United States. After specifying the models for cow inventories and milk production per cow, total milk production is calculated for the industry. Using the forecasting power of each model, an in-sample forecast will be performed to determine the forecasted cow inventories and milk production per cow. Once the national inventory of milk cows (1000 head) and the milk production per cow (lbs. of milk/cow/month) have been forecasted, then total milk production will be calculated using equation 12:

(12) $PRODF_t = INV_t \times MPC_t.$

The forecasted total milk production is denoted by *PRODF*. To determine the reliability of the predicted milk production from equation 12, the following regression (equation 13) is constructed to see how well the forecasted total milk production fit the actual total milk production data. This model will demonstrate the fit during time *t* of the forecasted total milk production to the realized national milk production. The model is a means to compare the forecasted total milk production with the actual total milk production occurring over time *t*:

(13) $PROD_t = PRODF_t + \mu_t.$

3.3 Feed Cost and Cumulative Profit

An assumption of the model is that feed costs impact the choices dairy producers make in regards to management of the herd and ultimately the total milk production. Cow inventories and milk production per cow contribute to the total milk production of the farm and the industry as a whole. However, previous literature indicates that profit may have more explanatory power in regards to the dependent variables of cow inventories and milk production per cow. The idea of a profit margin based on revenue ($/cow/day) and feed cost ($/cow/day) can be furthered to an idea of cumulative profit.

Cumulative profit is a measure of the profit received not only this month, but also in the previous months at some specified time period, *t*. This is based on the assumption that profit in time, *t*, is a result of management decisions made in time *t-1*, *t-2*, etc. In addition to the influence of the current month's profit there may be an influence from the previous month's profit compounded with today. Furthermore, as a certain amount of time passes with both positive and negative profits occurring, the cumulative profit will demonstrate how long producers are capable of surviving with negative profit.

To reflect this idea that an accumulation of profit over some time period, *t* equation 14 calculates the profit as it accrues over time:

(14) $$PRC_m = \sum_{t=0}^{m} Revenue_t - \ Feed\ Cost_t,$$

where cumulative profit over some time period, *m*, is denoted by *PRC*. The length of the time periods to determine cumulative profit is calculated based on intervals of three months extending out 24 months (i.e., *m* = 0, 3, 6, 9, 12, 15, 18, 21, and 24). The value of *t*, represents the specific time period for revenue and feed costs ($/cow/day). This calculation is estimated for all cumulative profits of *m*.

The correct number of months for cumulative milk profit data is tested by observing the improvement of the R-squared of the models ran with feed cost, no cumulative profit, three months of cumulative profit, six months of cumulative profit, and all other months of cumulative profit. Additional factors of comparison are the statistical significance of the variable and the regression. This relationship can be shown graphically by overlaying the cumulative profit over some time period *m* with the cow inventory or milk production per cow variables. Profit calculations will be compared between the two rations developed by ARFJA and Robinson as mentioned in Section 2.4.2. Although the Robinson ration is a more realistic representation of a cow's daily consumption, the ARFJA ration captures more of the implicit costs within the formulation. These rations will be compared only in the foundational models to quantify the difference between the two rations. The forecasting models will use the Robinson ration formulation.

3.4 Autoregressive Model

An autoregressive model is the initial foundational forecasting model to which all other model specifications must compete. It follows the basic construction that the value today is the same as yesterday with some adjustment for seasonality and trend. This model will be constructed as an initial step of the forecast to which the other three forecasting models will be compared. The model is specified in the following equation:

(15) $$Class3\ Price = Class3\ Price_{t-1} + Seasonality + Trend$$

This model will also be forecasted using an ex-post and out-of-sample method to compare between models. The ex-post forecasts of the various models will be used to determine if any other model has improved upon the forecasting abilities of the autoregressive model. Essentially, the autoregressive model sets the bar to which all other models must exceed. This is because it is based on rational expectation that yesterday's price determines today's price. If the model is not superior to this forecast then the estimation is considered a non-insightful endeavor.

3.5 Log of Consumption Model

A linear model is constructed to represent the basic relationship between consumption of cheese products and changes in Class III milk prices centered on the knowledge that cheese prices are highly correlated with Class III milk price. Though a crude estimate, previous experience in the hog market has shown simplistic analysis similar to equations 16-18 proves accurate in forecasting prices. The model is constructed via a series of calculations to determine overall consumption per capita.

(16) $$CHSUP = CHPROD + CHSTOR + CHIMP,$$

where *CHSUP* is the cheese supply to the market in thousands of pounds of cheese. It is a function of the cheese produced by the industry (*CHPROD)*, the cheese in cold storage (*CHSTOR)*, and the cheese imported into the market (*CHIMP)*. Through the addition of cheese production, storage, and imports the total cheese supply is calculated.

Subsequent calculations are made to determine the domestic consumption variable as a function of the cheese supply and the cheese exports which are occurring in the market place. The domestic consumption variable is calculated in Equation 16.

(17) $$DCONS = CHSUP - CHEXP.$$

DCONS, is the consumption of cheese in the United States, which is a measure of both the domestic supply, *CHSUP* (that cheese supplied to the market place as calculated in Equation 16), minus the cheese exported (*CHEXP*) to other markets from the United States.

The basic premise of this model is that the change in domestic consumption and the milk equivalent exports are influential explanatory variable on the Class III milk price. This is represented in the following equation:

$$(18) \quad LNCLASS3_t = \beta_0 + \beta_1 LNDCONS_t + \beta_2 EXP_t + \beta_3 D_i + \beta_4 Trend + \mu_t.$$

LNCLASS3 is the log of the Class III milk price in time, *t*, and is the dependent variable of this regression. *LNDCONS* is the log of the total domestic consumption of cheese in time *t*, *EXP* represents the milk equivalent exports in time *t*, D_i is a seasonality monthly dummy variable, *Trend* is the trend variable, and μ represents the error associated with the model in time *t*. A trend is used in this model to represent the change in the Class III milk price that occurs over the time period; this variable captures the inherent change that occurs in an industry due to developments over time that are not quantified like technology, inflation, etc.

This model reflects the influence of a percent change in cheese consumption on a percent change of Class III milk price, while accounting for seasonality and trend patterns. It is estimated as a log-log to reflect the elasticity of consumption and how responsive Class III milk price is to changes in consumption. Although simplistic, this model shows the relationship between supply and demand, and is capable of forecasting Class III price.

3.6 VAR Model

Vector autoregressive (VAR) models estimate multiple endogenous variables in one regression, with some exogenous variables included in the model. These endogenous variables are coordinated together to forecast using an autoregressive method, with multiple dependent variables. The idea behind the VAR model is to specify a simple model (meaning few endogenous variables) to prevent possible errors that often occurs within the VAR models. An approach like this will create a more powerful forecasting model because of its simplistic nature, instead of an 'everything but the kitchen sink approach'. The VAR model developed in this study is summarized as follows in Equation 19:

$$(19) \qquad Y_t = \begin{Bmatrix} CLASS3 \\ PROD \\ EXP \\ CHSTOR \\ PRF12 \\ IMP \end{Bmatrix}$$

$$X_t = \begin{Bmatrix} Seasonal\ Dummy \\ Trend \end{Bmatrix}$$

Y_t represents the endogenous variables used within the VAR model and the X_t are those exogenous variables used within the model. *CLASS3* is the Class III milk price, *PROD* is the total milk production, *EXP* is a measurement of milk equivalent exports, *IMP* is the milk equivalent imports, *CHSTOR* is the total pounds of cheese in cold storage, and *PRF12* is the cumulative profit over 12 months. The detailed specification of this model is included in Equation 20.

$$(20) \qquad \mathrm{CLASS3}_t = \alpha_1 + \sum_{j=1}^{k} \beta_{1j}\mathrm{CLASS3}_{t\text{-}j} + \sum_{j=1}^{k} \gamma_{1j}\,\mathrm{PROD}_{t\text{-}j} + \sum_{j=1}^{k} \delta_{1j}\,\mathrm{EXP}_{t\text{-}j} + \sum_{j=1}^{k} \varphi_{1j}\,\mathrm{CHSTOR}_{t\text{-}j} + \sum_{j=1}^{k} \omega_{1j}\,\mathrm{PRF12}_{t\text{-}j} + \sum_{j=1}^{k} \vartheta_{1j}\,\mathrm{IMP}_{t\text{-}j} + \beta_{2j}\mathrm{D}_{1i} + \beta_{3j}\mathrm{trend}_{1i} + \mu_{1t}$$

Equation 20 is a more detailed specification of the VAR model and represents the interactions that are occurring between the endogenous variables in an autoregressive form. There are five other equations which use the other five endogenous variables of *PROD, EXP*, *IMP*, *CHSTOR*, and *PRF12* as the dependent variables. *CLASS3* is the Class III milk price, *PROD* is the pounds of total milk production, *EXP* represents the pounds of milk equivalent exports, *CHSTOR* is the total pounds of cheese in cold storage and *PRF12* is the cumulative profit over twelve months.[3] These variables are interacting with a lag of *j=1to k* where, *k=2* over the time period, *t*. It was determined *k=2* through comparisons of various lag lengths. D_i represents the seasonal dummy variables and *trend* represents the linear trend incorporated into the unrestricted VAR model.[4] The error terms, of μ are a measurement of the stochastic error terms which are called impulses or shocks in VAR models (Gujarati and Porter, 2009). The *PROD* variable, representing total milk production over time period, t, is based on the forecasts of both the ex-post and out-of-sample models for milk cow inventory and milk production per cow.

When developing a VAR model, a serious source of error occurs when cointegration remains unaccounted for. Generally speaking, cointegration means variables share a common relationship between them. The Engle Granger Cointegration test is employed to examine data used within the VAR model. This commonly used test is based on the following assumption in equation 21:

(21) $$ay_{1t} + by_{2t} + cy_{3t} + \cdots + ny_{nt} = e_t.$$

---

[3] Milk equivalent exports and imports were chosen in lieu of cheese because of the ability to transform products.
[4] A trend variable is used in the unrestricted VARs, but is excluded from the restricted VAR because the cointegrating equations have previously incorporated a trend relationship into the estimation.

The variables y_1, y_2, $y_{3,}$ and, y_n represent those endogenous variables in time, *t*, used within a VAR model, that share a common relationship among them, where *n* is equal to the number of endogenous variables used within the VAR. Coefficients of *a, b, c,* and, *n* are representative of those values which determine the cointegrating regression of the endogenous variables; it is a measurement of the relationship shared among the endogenous variables. These values are equal to the error term, $e_{t,}$ because it is the method by which the cointegration can be calculated. This is because without cointegration the error term absorbs the relationship among the endogenous variables used in the VAR.

Gujarati and Porter (2009) state that two variables will be "cointegrated if they have a long-term or equilibrium, relationship between them" (Pg. 762). Once cointegration has been tested for, then the relationship between the variables must be enforced within the model. The cointegrated model enforces the relationship that exists among the variables before they are used in the VAR. The model must be re-estimated using the correction terms associated with the cointegration.

3.7 Partial Equilibrium Model

The final model specification is based on a simultaneous equation approach. The specification of the model is grounded on the supply and demand relationships between the various marketing levels: retail, wholesale, and farm. Within a given industry, prices can carry up- or downstream. In other words, farm-gate prices can influence wholesale prices which in turn impact retail prices, or changes in prices at the retail level can influence the prices at the wholesale and farm-gate levels.

In the case of the Class III milk price-forecasting model, the simultaneous equations model contains endogenous price variables throughout the different marketing levels. This model will be estimated using Two Stage Least Squares (2SLS) and Three Stage Least Squares (3SLS) Regressions. These two methods estimate the system of equations by using a step process, by which the residuals of the previous regressions define the coefficient estimates in the final step. In the case of 3SLS, this process is done in three steps and it differs from 2SLS because it uses cross equation correlation. However, it will be necessary to avoid the use of OLS estimates because of the inconsistent and inefficient estimators, which occur when estimating over identified simultaneous equations. Thus, the model must use other estimators to determine the regression. 2SLS and 3SLS are chosen because these models can estimate over-identified equations.

If a system of equations is just identified, OLS can be used as the estimator. However, in this particular case the system is over-identified and OLS is unable to estimate unbiased and efficient estimators. To correct for the bias, we must use a 2SLS and a 3SLS regression. A unique feature of these two methods is the utilization of instrumental variables, which are the exogenous variables that allow the model to estimate the coefficients through a partial equilibrium method despite the over-identification that exists. A problem which can occur among instrumental variables is perfect serial correlation; this will be tested for when choosing instrumental variables. This problem occurs because the 2SLS and 3SLS regressions are unable to estimate the parameters because of the occurrence of a near singular matrix. To test for the presence of near or perfect serial correlation, correlation coefficients were calculated for all of the instrumental variables and the specification of the partial equilibrium model was chosen. The 2SLS and 3SLS specification is shown in equations 22 to 24:

(22) Retail:

$$P_r = \alpha_1 + \beta_1 Q_{DR} + \beta_2 INC + \beta_3 FFD + \beta_4 P_r(-1)$$
$$Q_{SR} = \alpha_2 + \beta_5 P_r + \beta_6 P_w + \beta_7 P_{fe} + \beta_8 IMP + \beta_9 Q_{SR}(-1) + \beta_{10} SEAS + \beta_{11} TREND$$

(23) Wholesale:

$$P_W = \alpha_3 + \beta_{12} Q_{DW} + \beta_{13} P_r + \beta_{14} EXP + \beta_{15} P_W(-1)$$
$$Q_{SW} = \alpha_4 + \beta_{16} P_w + \beta_{17} P_C + \beta_{18} STOR + \beta_{19} SEAS + \beta_{20} TREND + \beta_{21} Q_{sW}(-1)$$

(24) Farm Level:

$$P_C = \alpha_5 + \beta_{22} Q_{DF} + \beta_{23} CPI^d + \beta_{24} SEAS + \beta_{25} TREND + \beta_{26} P_C(-1)$$
$$Q_{SF} = \alpha_6 + \beta_{27} P_C + \beta_{28} INV + \beta_{29} MPC + \beta_{23} Q_{sF}(-1)$$

At the retail level, the quantity demanded and supplied, represented by Q_{DR} and Q_{SR}, respectively, is based on the consumption of cheese. The demand equation at the retail level is an inverse demand equation in which retail price, $P_{r,}$ is a function of the quantity of cheese consumed (Q_{DR}), income (*INC)*, and fast food development (*FFD*). An inverse demand equation was chosen to allow full estimation of all endogenous variables, including the endogenous prices. Additionally, the retail demand function is a function of seasonality and a trend variable. The supply equation is a function of retail price (P_r), wholesale price (P_w), milk equivalent imports (*IMP*), seasonality, trend and a lag of the quantity of cheese consumed ($Q_{SR,\ t-1}$).

The wholesale demand equation is an inverse demand equation with the wholesale price of cheese set as a function of quantity demanded of cheese produced (Q_{SW}), the retail price (P_r), milk equivalent exports (*EXP*), and a lag of the wholesale price ($P_W(-1)$). The exogenous variables of exports and the lag of wholesale price allow the estimation of this system by converting the exogenous variables to instrumental variables. The supply equation is based on the quantity of cheese produced (Q_{SW}), which is a function of wholesale price (P_w), price of Class III milk (P_c), a fuel price index (P_{FE}), imports (*IMP*), seasonality, trend variables, and a lag of the quantity supplied of cheese produced.

The farm level demand equation is an inverse demand equation, with the Class III milk price functioning as the dependent variable (P_C). As explanatory variables, the demand equation uses the consumer price index of the dairy industry (CPI^d), the wholesale price of cheese (P_W), quantity of milk produced (Q_{DF}), seasonality, trend, and lagged Class III milk price ($P_{C,t-1}$). The CPI^d is attempting to measure the amount consumers and wholesalers spend on dairy products such as milk, cheese, butter, etc. It was chosen as an explanatory variable for the farm level demand equation because of its potential of measuring the relative use and preference of dairy products over time. The supply equation relies on the production of milk (Q_{SF}) as a function of Class III milk price, milk cow inventory (*INV*), milk produced per cow (*PPC*), and a lagged value of the quantity of milk produced ($Q_{SF,\ t-1}$).

The identification of the system is concerned with the balance between exogenous and endogenous variables. To allow a model to function properly using OLS, the system must be just identified. This implies that there exist enough exogenous variables in relation to the endogenous variables to fully explain the model. However, in some cases, as well as this one, over-identification can occur within the model and the researcher must rely on two stage least squares (2SLS) or three stage least squares (3SLS). This regression model is functional as long as the instrumental variables are identified to allow the 2SLS and 3SLS to function properly. Instrumental variables prevent the errors from correlating and are found by using variables which are unique to the model and exogenous. The identification of unique exogenous variables is discussed in Table 3.1.

Table 3.1. Simultaneous equation identification of endogenous variables

Market Level	*Equation*	*Endogenous Variables*	*Unique Exogenous Variables*	*Instrumental Variables*
Retail *Q =Cheese Consumed*	$P_r = Q_{DR} + INC + FFD + Q_{DR-1} + P_r(-1)$	$P_{R,}$ Q_{DR}	INC, FFD, $P_r(-1)$	INC, FFD, SEAS, TREND, $P_r(-1)$
	$Q_{SR} = P_R + P_W + P_{FE} + IMP + D_i + Trend + Q_{SR}(-1)$	P_R, $P_{W,}$ Q_{SR}	$P_{FE,}$ IMP, $Q_{SR}(-1)$, SEAS, TREND	$P_{FE,}$ IMP, $Q_{SR}(-1)$
Wholesale *Q = Cheese Produced*	$P_W = P_R + Q_{DW} + EXP + P_W(-1)$	P_R, $P_{W,}$ Q_{DW}	EXP, $P_W(-1)$	EXP, $P_W(-1)$
	$Q_{SW} = P_W + P_C + P_{FE} + CHSTOR + D_i + Trend + Q_{SW}(-1)$	P_W, P_C , $P_{FE,}$ Q_{SW}	CHSTOR, SEAS, Trend, $Q_{SW}(-1)$	CHSTOR, SEAS, Trend, $Q_{SW}(-1)$
Farm Level *Q = Milk Produced*	$P_C = P_W + Q_{DF} + CPI_{DAIRY} + P_C(-1)$	P_W, $P_{C,}$ Q_{DF}	$CPI_{DAIRY,}$ $P_C(-1)$	Seas, Trend, $CPI_{DAIRY,}$ $P_C(-1)$
	$Q_{SF} = P_C + INV + PPC + Seas + Trend + Q_{SF}(-1)$	$P_{C,}$ Q_{SF}	Seas, Trend, INV, PPC, $Q_{SF}(-1)$	INV, PPC, PCUM, $Q_{SF}(-1)$

The instrumental variables are functions of variables that allow the model to accurately estimate 2SLS and 3 SLS. As seen in Table 3.1, instrumental variables (IVs) are determined based on the unique exogenous variables and those dummy and lagged variables which are exogenous to the model. As such, they are functions of themselves, which allows the model to adjust the residuals allowing the model to be unbiased and efficient. Without IVs we are unable to estimate an efficient model because the residuals are inaccurate.

The previous sections have been concerned about the theory behind the creation of the forecasting models and the steps that occurred to create the six models. The methodology section also addressed the foundational models such as milk cow inventory and milk production per cow, which are primary models for forecasting milk production. The next section will address the accuracy of the models using an ex-post method as the comparison and evaluating the out of sample forecasts. The final section will provide an application of the out-of-sample forecasts to real life. Specifically determine at what point a producer should hedge in the futures Class III milk market, based on the evaluation of production costs and their relationship with futures contracts.

3.8 Model Comparisons

The six forecasting models described above will be evaluated with two objectives in mind. The first objective is to create accurate models and compare the correctness of ex-post forecasts across models. The second objective will be to estimate an out-of-sample forecast of the Class III milk price and once again analyze the accuracy of the prediction. The first objective will be accomplished by utilizing an ex-post method for each individual model and comparing their accuracy through analysis of the regression and Root Mean Square Error (RSME). An ex-post evaluation is often used to “test the key attribute of parameter constancy” (Clements and Hendry, Pg. 5).

The initial step of the ex-post method is to estimate all six models using data from January 2000 to July 2010. By allowing forecasts out two years, there will be more data points to show the accuracy of the forecast. The ex-post estimated models would be used to forecast out Class III milk price two year through July 2012. Once the forecast has been completed for in-sample data, the RMSE will be calculated using the following equation:

(25) $$RMSE = \sqrt{MSE} = \sqrt{\sum_{i=1}^{n} \frac{(X_{1,i} - x_{2,i})^2}{n}}.$$

RMSE is the Root Mean Square Error, which is the square root of Mean Square Error, MSE. The actual specification of this equation is the sum of the squared difference of the forecasted

Class III milk price ($x_{1,i}$) and the actual Class III milk price ($x_{2,i}$). The RMSE will allow a comparison of the models to determine which ex-post model has a lower RMSE, meaning that the forecasts are closer to the actual observations of Class III milk price. This process standardizes the accuracy level of the predicted Class III milk price and allows the comparison of the prediction across the models.

The additional step is to regress the forecasted Class III milk prices against the actual prices. This will show the goodness of fit for each model and allow for a second assessment of the predicted prices, as seen in the following equation:

(26) $$CLASS3_t = \alpha + \beta_1 \widehat{CLASS}3_t + \mu_t,$$

Where CLASS3 is the variable for the actual Class III milk prices observed over the time period of January 2000 to July 2012 and $\widehat{CLASS}3_t$ represents the predicted prices of Class III milk over the same time period, and μ_t represents the error term of the regression.

This regression above will compare the results of each of the six models against the actual Class III milk prices to evaluate the ex-post forecasts. This final regression (Equation 26) essentially shows the correlation of the two variables, which the R-squared of the forecasted prices is the square of the correlation coefficient associated with the forecasted and the actual Class III milk prices.

The ex-post method will be used initially for each model because it gives an estimation of the accuracy to which models may predict when they are used for out-of-sample price forecasts. It must be noted that the results of the ex-post model comparisons will hold true for the out-of-sample forecasts models because the out-of-sample model contains an additional two years of data and also is forecasting using estimations into the coming two years.

The out-of-sample forecast models are based on the same variables as the ex-post method; to conduct an out-of-sample forecast of Class III milk prices from August 2012 to July 2014. Out-of-sample is similar to an ex-ante analysis because they both use only data available at a particular point in time. The difference is that ex-ante forecasts will compare against the actual data (in this case Class III milk price) as the data is observed over time. An out-of-sample method forecasts data into the future based on the already known data as in the ex-ante case, however it is not essential to compare with actual results at a later date in time. The models will be compared based on conclusions of the ex-post analysis above and the superior model in terms of Class III milk price forecasts will be determined.

An additional analysis of the out-of sample models is to conduct a Diebold-Mariano test which uses the forecasts of the different models and the actual data to compare the models. This test determines the statistical significance of the forecasted Class III milk price from the other forecasted prices. The Diebold-Mariano test determines which forecasts from the individual models are statistically insignificant from each other. At some point when comparing the various regressions the forecasts will be statistically significant from another forecast. This analysis determines which models are essentially the same in their forecasting powers for out-of-sample forecasts. The equation of the Diebold-Mariano test is seen below in equation 27:

(27) $$ld_t = (Y_t - \hat{Y}_{t-1}^{AR_1})^2 - (Y_t - \hat{Y}_{t-1}^{AR_2})^2.$$

The loss differential (ld_t) is equal to the difference between the autoregressive models forecasts, Y^{AR1} and Y^{AR}. In other words, this test looks at the difference between the forecasts of the various models and determines if they are statistically significant from each other. The Diebold-Mariano test will be used to determine at which points the top performing models are statistically different from the bottom performing models (Fantazzini, 2007).

Once the models have been estimated and tested for accuracy, it is essential to apply the information gained and determine the optimal time for a producer to make decisions based on the knowledge they have about Class III milk price forecasts and the costs of feed they are experiencing today. This will also work well for producers who are desirous to know the point at which they should hedge to lock in their margin.

3.9 Hedging Analysis

When commodities are traded on a futures market, like livestock and grains, an interesting phenomenon plays out between storable, semi-storable and non-storable commodities. The underlying assumption of a futures market is that the futures price represents the price at which the commodity will sell on the cash market at that future date. However, the interesting phenomenon which occurs is that for semi-storable and non-storable commodities the price relationship between the actual cash price and the futures contract price does not follow the previous assumption. Dairy products, like other livestock products, are a non-storable or semi-storable commodity. Thus, the absence of the relationship between futures contracts and cash prices has caused many producers, hedgers, and speculators to avoid the futures market for dairy commodities. In other words, a producer is deterred from participating in the futures market because they are unable to consistently determine if the futures price is representative of the cash price in a particular future month. Thus, low volume, or thin markets, in the futures market for dairy commodities is observed.

The assumption behind this regression to determine the hedging horizon is that as contract expiration approaches in semi-storable and non-storable commodities, the market price relationship between feed cost or some other variable and the futures prices deteriorates to reflect current market conditions. This is partially in result to the fact that these products are subject to the current market conditions when compared to storable commodities as they are unable to be withdrawn from the market for extended periods of times. Thus the futures price is more likely to reflect the current market conditions.

As a result of the difficulty of determining the cash price based on the known futures price, at some given month, a different method will be used. Specifically, an evaluation of the months previous to contract expiration will be conducted to see if there a relationship between costs associated with milk production and the futures contract price. Based on work by Koontz, Hudson, and Hughes (1992) in the lean hog and cattle markets, an examination of the relationship between a lagged financial component and the futures prices observed in the market for Class III milk will be performed, using the following model:

(28) $$CP\ (t-i)_k = \alpha_0 + \beta_1 PR^*(t-j)_k + \rho * CP_{t-1} + \varepsilon_k,$$

where *CP* denotes the average of the monthly prices of futures contracts for Class III milk on the Chicago Mercantile Exchange (CME) which are expiring in month *t* with *i* months remaining for trade. CP_{t-1} denotes the lag of the dependent variable, with ρ as the coefficient of the autoregressive term. The observations occur over futures contracts denoted by *k.* In the case of the Class III milk futures market a contract is associated with every calendar month.

The months prior to the delivery month *t*, are denoted by *i*. PR^* denotes the profit variable of costs (either cumulative or not) which is *j* months prior to the delivery month *t*. The specification of this model will be determined based on which financial variable, either feed cost or cumulative profit, is more significant to the model. The results of this model will determine and recommend the point at which hedgers should participate in the futures market based on the cumulative profit they are experiencing. This will allow producers to lock-in a margin through hedging without experiencing the increased volatility, which occurs near contract expiration in the Class III milk market.

CHAPTER 4: DATA

All data collected are measured on a monthly basis starting in January of 2000 through July of 2012. Data collection began in 2000 because of the pricing change which occurred in late 1998 (LMIC, 2012). In 1998 the structural outline of the milk pricing system was changed to the current classification of milk based on usage. Prior to the end of 1998, the milk price for manufacturing milk (the equivalent of Class III milk price) was used to represent the price producers would have been paid by wholesalers and this varies significantly from the current Class III milk price. As a result, many data sources consider the beginning of 2000 as the point at which the dairy pricing system was changed and consistent through the present. The change of the pricing strategy affected the ability to collect cheese and milk prices for the previous years. The ex-post analysis constructs the model using data from January 2000 to December 2009, with the forecast occurring over January 2010 to July 2012. The out-of-sample projection uses the previously created model to forecast from August 2012 to July 2014. Data associated with the hedging analysis is monthly data from January 2009 through July 2012. The variables, along with description, source and summary statistics used within this thesis are listed in Table 4.1.

Table 4.1. Dairy industry data summary statistics, January 2000 to July 2012

Variable	Symbol	Source	Unit	Mean	Maximum	Minimum	Std. Dev.
All Futures Contract	CONT	CME Group Class III Milk Futures	$/cwt.	15.65	21.52	15.41	1.42
All Milk Price	AMP	Calculated from USDA AMS-Announcement of Class and Component Prices	$/cwt.	15.31	22.10	11.00	3.03
Cheese Consumption	CONS	USDA ERS- Commercial disappearance of American cheese	1,000 lbs.	810.59	962.07	604.80	76.71
Cheese Production	CHPROD	USDA NASS-Dairy Products	1,000 lbs.	783,245.50	947,041.00	636,090.00	75,004.22
Cheese Storage	STOR	USDA NASS-Cold Storage	1,000 lbs.	849,976.70	1,083,198.00	631,293.00	115,992.50
Class III Milk Price	CLASS3	USDA AMS- Announcement of Class and Component Prices	$/cwt.	13.90	21.67	8.57	3.30
Cow Inventory (Dairy)	INV	USDA NASS- Milk Production	1,000 Head	9,147.45	9,334.00	8,986.00	87.54
CPI-Dairy	CPI	USDL Bureau of Labor Statistics	Index	116.36	137.46	99.19	11.41
Cull Cow Slaughter	CULL	USDA NASS- Cattle on Feed	Head	218,780.10	281,000.00	162,400.00	25,851.12
Fast Food Growth	FFG	USDL Bureau of Labor Statistics	Restaurants/mth	33,846.72	43,938.00	24,608.00	5,507.94
Feed Cost	FC	USDA WASDE	$/head/mth.	132.46	291.47	111.68	58.41
Income	INC	USDC Bureau of Economic Analysis- Per Capita Personal Income by State	Dollars	37,449.89	67,288.00	22,382.00	7,308.92
Milk Equivalent Exports	EXPORT	USDA FAS GATS- U.S. Exports of "Dairy Products"	1,000 lbs.	161,475.70	368,820.10	57,771.10	77,550.20
Milk Equivalent Imports	IMP	USDA FAS GATS- U.S. Imports of "Cheese" and Imports of "Other Dairy Products"	1,000 lbs.	78,983.27	114,040.00	52,140.55	12,122.78
Price Cheese	PCH	USDA NASS- Dairy Products Sales (Dairy Products Prices)	$/lb.	1.48	2.16	1.02	0.29
Price Cheese Retail	PRET	USDA AMS- National Dairy Retail Report	$/lb.	3.90	4.40	3.53	0.17
Price Cull Cow	PCULL	USDA AMS- Slaughter Cattle Summary	$/cwt.	49.88	87.70	33.00	11.90
Price Dairy Cow	PCOW	USDA NASS- Marketing Year Average Prices Received	$/head	1,562.85	2,020.00	1,240.00	224.18
Price Index Machinery	PMAC	USDA NASS- Agricultural Prices	Index	135.79	189.05	100.00	27.28
Price Wholesale	PWHOLE	USDA NASS- Dairy Products Sales (Dairy Products Prices)	$/lb.	1.74	2.45	1.24	0.31
Production Per Cow	PPC	USDA NASS- Milk Production	lbs./head/mth.	1,647.35	1,909.00	1,408.85	111.96
Profit Margin	PRF	Calculated Value based on USDA data	$/head/mth.	109.72	243.33	18.97	46.34
Profit 3	PRF3	Calculated Value based on USDA data	$/head/mth.	329.87	676.70	113.09	131.57
Profit 6	PRF6	Calculated Value based on USDA data	$/head/mth.	662.98	1,252.43	248.47	246.67
Profit 9	PRF9	Calculated Value based on USDA data	$/head/mth.	1,000.54	1,847.49	420.80	347.09
Profit 12	PRF12	Calculated Value based on USDA data	$/head/mth.	1,341.03	2,331.76	615.79	432.04
Profit 15	PRF15	Calculated Value based on USDA data	$/head/mth.	1,685.83	2,813.92	846.47	500.82
Profit 18	PRF18	Calculated Value based on USDA data	$/head/mth.	2,034.15	3,225.50	1,026.77	553.98
Profit 21	PRF21	Calculated Value based on USDA data	$/head/mth.	2,385.66	3,598.44	1,225.41	590.54
Profit 24	PRF24	Calculated Value based on USDA data	$/head/mth.	2,738.31	3,941.71	1,465.56	612.48
Replacement Heifers	REP	USDA NASS-Cattle	Head	4,047,602.00	4,568,200.00	3,600,000.00	235,738.30
Total Milk Production	PROD	USDA NASS- Milk Production	1,000,000 lbs.	15,072.77	17,692.00	12,867.00	1,089.16

CHAPTER 5: RESULTS AND DISCUSSIONS

The previous narration of this thesis has been laying the foundation for the results and discussion that will follow in this chapter. This chapter begins by determining the results of the ADF test for stationarity and outlining those variables which will be first differenced within the models (Section 5.1). The chapter will continue with a presentation of the results of the foundational models for cow inventory, milk production per cow, and total production in Section 5.2. The following section will address the results of the autoregressive model (Section 5.3); followed by the log of consumption model in Section 5.4. Section 5.5 will report the results of the vector autoregressive model and discuss the implications. Section 5.6 is concerned with the system of equations results and analysis. The comparison of the six models will then occur in Section 5.7. This section will compare the results of both the ex-post and out-of-sample forecasts, which are made for the six models. The final section 5.8 will be concerned with the hedging analysis and determination of the point at which the relationship between cumulative profit and the futures contract prices fall apart. As a side note, all reported variables with values less than 0.0001 are denoted as 0.0001*.

5.1 Data Testing Results

All variables used within the models were tested for stationarity using the Augmented Dickey Fuller (ADF) test. This test looks at the residuals of the variable to see if the mean and variance fluctuate throughout the data period. Results of the ADF test are in Table 5.1.

Table 5.1. Results of the Augmented Dickey Fuller test

Variable	ADF Test Statistic	P-value	First Difference
All Milk Price	-2.4536	0.1291	Yes
All Contract Prices	-0.9010	0.7875	No
Cheese Consumption	0.0671	0.9623	Yes
Cheese Production	0.3783	0.9814	Yes
Cheese Storage	-1.0032	0.7511	Yes
Class III Milk Price	-2.6312	0.0890	No
Cow Inventory	-2.0077	0.2834	Yes
CPI-DAIRY	-0.9309	0.7761	Yes
Cull Cow Slaughter	-0.9551	0.7678	Yes
Fast Food Growth	0.2869	0.9769	Yes
Feed Cost	-0.2358	0.9741	Yes
Milk Equivalent Exports	-1.1337	0.7020	Yes
Milk Equivalent Imports	-1.2337	0.6592	Yes
Income	-2.4955	0.1183	Yes
Price Cheese	-2.8724	0.0511	Yes
Price Cheese Retail	-3.2418	0.0195	No
Price Cow	-2.6304	0.0892	No
Price Cull Cow	0.2351	0.9740	Yes
Price Index Machinery	2.2934	1.0000	Yes
Price Wholesale	-3.4493	0.0108	No
Production Per Cow	0.1649	0.9694	Yes
Profit Margin	-2.9527	0.0415	No
Cumulative Profit 3 Months	-3.0081	0.0362	No
Cumulative Profit 6 Months	-4.1790	0.0010	No
Cumulative Profit 9 Months	-2.9055	0.0469	No
Cumulative Profit 12 Months	-4.2685	0.0007	No
Cumulative Profit 15 Months	-3.7693	0.0039	No
Cumulative Profit 18 Months	-3.7695	0.0039	No
Cumulative Profit 21 Months	-4.0429	0.0016	No
Cumulative Profit 24 Months	-3.1096	0.0277	No
Replacement Heifers	-0.5627	0.8742	Yes
Total Milk Production	0.1743	0.9701	Yes

The above table indicates that all variables, excluding the profit variables, Class III milk price, retail price, and wholesale price are non-stationary and as a result must be first differenced to be used within the models at a 90% confidence level. Initial attempts at forecasting, first differenced those variables which are not stationary with 95% confidence such as, the Class III milk price. However this led to poor forecasting results of the Class III milk prices; for example, the Class III milk prices became negative for two of the six forecasting models. An additional variable which will not be first differenced is the milk production per cow as it is a biological variable. Biological data as indicated in the methodology should not be first differenced despite the confirmation of stationarity as indicated by the ADF test. All contract prices will also remain non-stationary due to the treatment of other price variables in this research.

5.2 Foundational Model Results

Section 5.2.1: Cow Inventory Results

The cow inventory regression is modeled based on the relationship between the movement of cattle from replacement inventories and the milk cow inventory, and also from the milk cow inventory to the slaughter cow inventory. There is also a financial variable included to quantify the effect previous economic choices have on the decisions individual producers and the industry as a whole make to manage the milk cow inventory; this is the profit or cumulative profit variable. Seasonality is also incorporated into this model because it is assumed that the inventory of cattle varies by month due to fluctuating inventories and weather patterns, but also on events like drought, and low milk price, that may be more prominent in certain months.

The initial step in calculating the cow inventory regression was to determine the variable to be chosen as a representative of financial conditions. To determine the financial variable, the following variables calculated from the two ration formulations (ARFJA and Robinson rations) were interchanged in the model's construction to examine the goodness of fit and significance of the parameter's coefficient: feed cost, profit, and cumulative profit over three, six, nine, twelve, fifteen, eighteen, twenty-one, and twenty-four months. The results from all regressions were compared against each other and profit in the current period was chosen to represent the financial impact on milk cow inventory. Cumulative profit over twelve months was the secondary choice; however the coefficient estimate was insignificant. The cumulative profit variable indicated that increases in accumulated profit over time increase cow inventories.

The cumulative profit variable was calculated based on the difference between milk revenue per cow per month and the feed cost per cow per month. Essentially, the cumulative profit is the profit per cow per month summed over a certain time frame. It was calculated to show that decisions are not made primarily based on variable costs or the current month's profit, but they are based on the accumulation of profits and losses over a given time frame which is variable from individual to individual and also from decision to decision. Figure 5.1 illustrates that as cumulative profit changes there is a high chance that milk cow inventories will also change in that time period or in some time period shortly after.

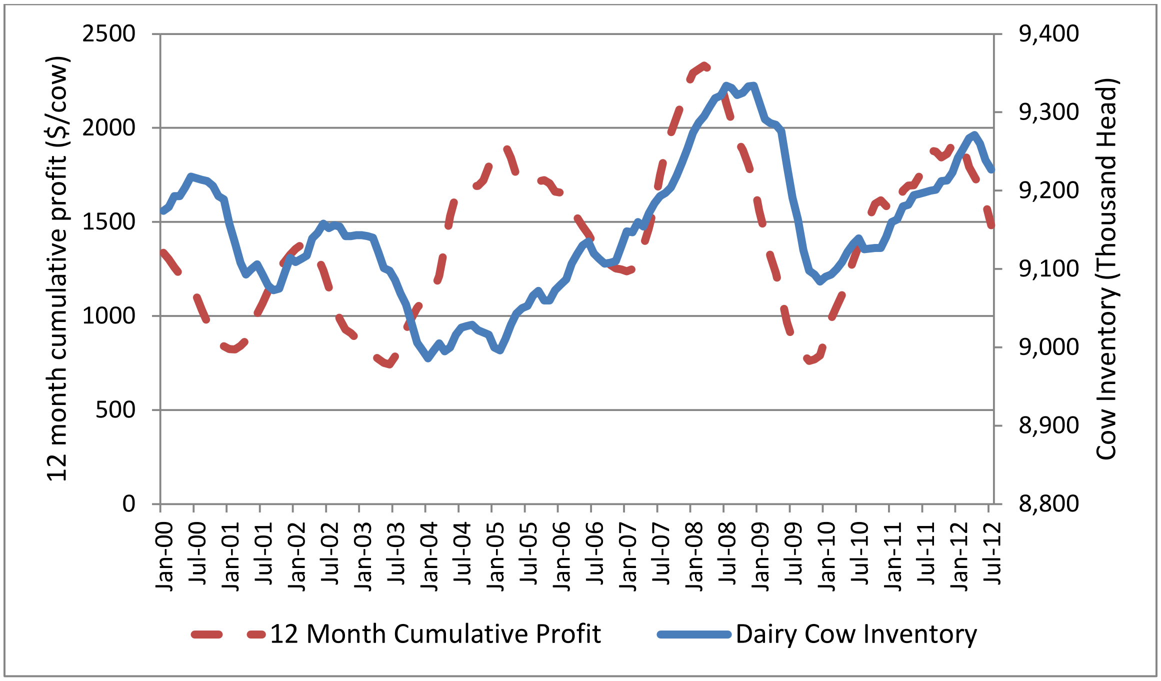

Figure 5.1. Cow inventory and 12 month cumulative profit (Robinson Ration), January 2000 to July 2012

The cow inventory model for the ex-post forecast was calculated using monthly data from January 2000 to December 2009. With an R-squared value of 0.6697 and a significant F-statistic, the results indicate the variables chosen are helpful in explaining the milk cow inventory over the specified period (Table 5.2).

Table 5.2. Cow inventory 12 month cumulative profit (ARFJA), Jan. 2000 to Dec. 2009

Variables	Coefficient	Standard Error	P-Value
Intercept	-28.5686	8.9010	0.0018
CULLD	-0.0001	0.0001	0.0831
CULLD(1)	-0.0002	0.0001	0.0062
CULLD(2)	-0.0002	0.0001	0.0067
REPD(3)	0.0002	0.0001	0.0860
PRF12 ARFJA	0.0194	0.0030	0.0001*
Feb	1.9233	4.2340	0.6507
Mar	6.2816	4.5632	0.1718
Apr	0.3753	5.0464	0.9409
May	35.2008	17.3437	0.0452
Jun	28.9279	16.5324	0.0834
Jul	26.4144	16.9234	0.1219
Aug	30.4115	16.5572	0.0693
Sep	31.2797	16.7994	0.0657
Oct	30.8855	16.5320	0.0648
Nov	6.5754	4.3278	0.1320
Dec	10.1545	3.7888	0.0087
Trend	0.0536	0.0436	0.2214
INV(1)	0.4085	0.0947	0.0001*
R-squared: 0.6697 Durbin-Watson = 1.9506		F-Stat(19,115)=10.8150 Prob. of F-stat = 0.0001*	

The model represented in Table 5.2 uses the twelve month cumulative profit variable calculated from the ARFJA ration which is an unrealistic estimation of a dairy ration, however the higher cost of the ration may account for other variable costs of dairy production. However, the intent of this variable is to represent those costs (mainly feed) related to milk production as a result a twelve month cumulative profit variable associated with the realistic feed cost, and was estimated using the following regression (Table 5.3). This cow inventory regression will be used in place of the cow inventory regression involving the ARFJA ration.

Table 5.3 Cow inventory 12 month cumulative profit (Robinson), Jan. 2000 to Dec. 2009

Variables	Coefficient	Standard Error	P-Value
Intercept	-42.4526	9.9400	0.0001*
CULLD	-0.0001	0.0001	0.0698
CULLD(1)	-0.0002	0.0001	0.0055
CULLD(2)	-0.0002	0.0001	0.0064
REPD(3)	0.0002	0.0001	0.0515
PRF12 Robinson	0.0213	0.0040	0.0001*
Feb	1.7514	4.2257	0.6795
Mar	6.2357	4.6448	0.1826
Apr	0.2577	5.1926	0.9605
May	40.8411	18.2621	0.0276
Jun	34.0646	17.4275	0.0535
Jul	31.8008	17.8621	0.0782
Aug	35.8542	17.4807	0.0430
Sep	36.8446	17.7270	0.0403
Oct	36.4068	17.4387	0.0395
Nov	6.4023	4.4117	0.1500
Dec	9.9722	3.7951	0.0100
Trend	-0.1382	0.0531	0.0108
INV(1)	0.4706	0.0910	0.0001*
R-squared: 0.6544 Durbin-Watson = 1.9935		F-Stat(19,115)=10.0969 Prob. of F-stat = 0.0001*	

CULLD represents the first difference value of the cull cow inventory and *REPD* is the inventory of replacement heifers in addition to its lagged quantities of the replacement heifer inventory. *PRF12* is the twelve month cumulative profit and this is the variable which changes between the two ration formulations (ARFJA and Robinson). *INV(1)* is the lag of the dependent variable, which is the milking cow inventory. All other variables are the seasonality dummies and the trend.[5]

Estimates of the model coefficient are economically accurate in their interpretation for both the models above using the different ration combinations. It is implied by the cull cow independent (*CULLD*) variable, and for both the current and lagged values, that as cull cow slaughter rates increase today and in the previous two time periods, then the milk cow inventory decreases in the current time period. This follows the observation that milk cow slaughter inventories essentially remove cows from the milk production herd and into the slaughter market. These results are statistically significant at the 90% confidence level for the cull cow inventory in time *t*, and at the 95% confidence level for the two lag lengths. The coefficient of the lagged replacement heifer rate (*REPD(3)*) indicates that as replacement heifer rates increase three months prior, there is an increase in milk cow inventory in the current time period. This supports the observation that a portion of the replacement heifer inventory three months ago is in the milk cow inventory today. These coefficients are statistically significant at the 95% confidence level.

An additional variable of interest is the cumulative profit variable which is interpreted to mean that as the accumulation of profit over time increases, then there occurs a subsequent increase in cow inventories. This concurs with the observation that increases in profit drive more producers into the industry and herd expansion of current operations.

Other significant parameters are seasonality and the autoregressive term. Seasonality is important to the model, especially for the months, May through October and December. These months support the conclusion that during the summer months and fall months when feed is

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[5] All regressions using other values of cumulative profit and feed cost based on the alternate rations are included in Appendix A.

more readily available, the milking cow inventory will increase. The trend is significant to this regression, meaning a steady decrease in cow inventories over time has occurred. It was determined that the second model will be used for forecasting purposes because of the realistic estimate of ration formulations.

Section 5.2.2: Milk Production per Cow Results

The production per cow varies seasonally due to weather impacts from extreme cold or heat and also the quality of feed available during particular points in the year. Knowing the impacts of the weather and other seasonal occurrences it is essential to base the model on seasonal components. Similar to the cow inventory model, a financial component was also included in this model.

A financial component is critical to determining milk production per cow because the financial situation of the producer will impact the quality and quantity of feed a producer chooses for his/her herd. Additionally, it will assist in determining how often the cows will be milked and how quickly they are re-bred. These are important to the milk production potential of an individual cow because all of these variables have the potential of decreasing or increasing the production of the cow due to management decisions.

In regards to the financial component for this particular model, the same methodology was followed to determine which financial measurement should be used. By alternating various financial variables such as feed cost, profits, and various cumulative profits within the production per cow inventory regression, the appropriate financial variable was determined based on the change in R-squared, significance of the regression as a whole, and correct economic interpretation of the financial variable's coefficient. The comparisons of the model indicated that the nine month cumulative profit should be used.

The results of the ARFJA ration will be presented first followed by those results using the nine month cumulative profit associated with the Robinson ration. As in the cow inventory models, the interpretation of the coefficients will not change significantly between the models so the interpretations will only be discussed once. The milk production (yield) per cow model using the ARFJA ration for the nine month cumulative profit is presented in Table 5.4 and includes data from January 2000 to July 2009.

Table 5.4. Milk yield per cow 9 month cumulative profit (ARFJA), Jan. 2000-Dec 2009

Variables	Coefficient	Standard Error	P-Value
Intercept	1501.7350	7.1509	0.0001*
PRF9 ARFJA	0.0152	0.0063	0.0178
CULLD	0.0000	0.0000	0.2928
FEB	-118.2792	4.5398	0.0001*
MAR	47.3888	4.8015	0.0001*
APR	13.9430	5.6721	0.0157
MAY	68.4538	5.7009	0.0001*
JUN	-14.6755	5.7875	0.0127
JUL	-15.3970	5.7923	0.0091
AUG	-39.3297	5.6948	0.0001*
SEP	-104.4938	5.6708	0.0001*
OCT	-58.8884	5.2927	0.0001*
NOV	-103.1821	5.0226	0.0001*
DEC	-32.2033	3.9196	0.0001*
T	2.2152	0.0779	0.0001*
PPC(1)	0.6125	0.0638	0.0001*
R-squared: 0.9886 Durbin-Watson = 2.2533		F-Stat(16,118)=587.6098 Prob. of F-stat = 0.0001*	

The above regression results are similar to the regression results presented below in Table 5.5. The models differ through the use of the two alternate rations. The model above uses the more expensive ration determined by ARFJA and the model in Table 5.5 uses the ration determined by the program managed by Robinson. These models are very similar in their R-squares and both regressions statistically significant as indicated by the F-statistic. The models differ in the significance of the nine month cumulative profit variable. The model based on the ARFJA ration is significant in the nine month cumulative profit variable at the 95% confidence level. The Robinson model is not significant in this variable as seen in Table 5.5.

Table 5.5. Milk yield per cow 9 month cumulative profit (Robinson), Jan. 2000-Dec 2009

Variables	Coefficient	Standard Error	P-Value
Intercept	1500.6620	9.5112	0.0001*
PRF9 Robinson	0.0090	0.0078	0.2542
CULLD	0.0000	0.0000	0.2862
FEB	-118.1809	4.5747	0.0001*
MAR	47.0699	4.8874	0.0001*
APR	13.5314	5.7959	0.0215
MAY	67.9181	5.8606	0.0001*
JUN	-15.3229	5.9667	0.0117
JUL	-16.1583	5.9762	0.0080
AUG	-40.0935	5.8709	0.0001*
SEP	-105.1396	5.8270	0.0001*
OCT	-59.3252	5.4211	0.0001*
NOV	-103.4502	5.1063	0.0001*
DEC	-32.3200	3.9575	0.0001*
T	2.1422	0.0879	0.0001*
PPC(1)	0.6437	0.0621	0.0001*
R-squared: 0.9881 Durbin-Watson = 2.2434		F-Stat(16,118)=565.0523 Prob. of F-stat = 0.0001*	

The coefficients which are specific to the milk production per cow models are *PRF9*, which is the cumulative profit over nine months. *CULLD* is the first difference of the cull cow inventory. All other variables in the model have been described previously in Chapter 4. Serial correlation has also been corrected in the model through the autoregressive term, which is indicated by the Durbin Watson statistic. This model is superior to other choices as it has a higher R-squared when compared to all models for the two ration formulations, the signs of the economic variables are correct and the nine month cumulative profit variable is the most significant within the ARFJA model.

The coefficients for all seasonality variables are statistically significant to the milk production per cow. The coefficient of the nine month cumulative profit can be interpreted to be as the nine month cumulative profit increases milk production per cow also increases. This supports our discussion above that as financial environments improve for producers they are more willing to pay for higher quality feed, additional labor, and more reproduction related expenses, consequently increasing milk production per cow. The trend variable, also significant, indicates that over time the milk production per cow has also increased due to several factors, including technological improvements. The lag of milk production per cow is contained in the autoregressive term and indicates that the milk production per cow of the previous time period has a positive influence on the milk production per cow in the current time.

Section 5.2.3: Total Milk Production Results

Now that the foundational models for milk cow inventory and milk production per cow have been constructed and evaluated, they are used to determine total milk production. Total milk production was regressed on predicted values of the milk cow inventory and milk production per cow models. Total milk production was determined to be influenced by the current cow inventories and the milk production per cow calculated in Section 5.2.1 and 5.2.2, using the Robinson ration. The regression output is presented in Tables 5.6.

Table 5.6. Total milk production regression (Robinson ration), Jan. 2000 to Dec. 2009

Variables	Coefficient	Standard Error	P-Value
Intercept	-970.2405	328.1537	0.0038
PPC	9.7412	0.2028	0.0001*
INV	0.2778	1.7977	0.8775
R-squared: 0.9551 Durbin-Watson = 0.3409		F-Stat(3,137)=1191.007 Prob. of F-stat = 0.0001*	

The results reported in Table 5.6 show that the milk cow inventory is not statistically significant. However, the sign of the coefficient could be considered correct if there is some small increase in total milk production if the cow inventories increase. The variable with more explanatory power is the milk production per cow, PPC. This coefficient suggests that as milk production per cow increases by one lb./cow/month, the total milk production increases by 9,741,200 lbs. of milk per month unit. The model is a significant estimation of total milk production as indicated by a high R-squared of 0.9551 and the statistically significant F-statistic. The Durbin-Watson statistic does indicate that there is evidence of positive auto-correlation. However, this was ignored as it was corrected for in later models and because the use of autoregressive terms did not improve the correlation.

These foundational models estimated above quantified the basic interactions occurring in the dairy industry, which are influential on total milk production. These models will serve as a basis for the models constructed to forecast Class III milk price. The remainder of the chapter will present the results of the six forecasts models, a comparison of the models, and then conclude with a hedging analysis of Class III milk price.

5.3 Autoregressive Model Results

An autoregressive (AR) model was constructed to represent the basic forecasting model to which all other forecasting will be compared. The basic concept behind this model is that the price of yesterday is the major determinant of the price today along with the conditioning variables of seasonality and trend. If more technical forecasting models are used to forecast Class III milk price, a major consideration is that they must be more accurate than this AR model, because the AR model serves as the benchmark (Pesaran and Timmermann, 2005). The models were created using an OLS regression of the present Class III milk price as the dependent variable with the independent variables being monthly dummy variables, trend, and a one period lagged Class III milk price. The results of the ex-post forecast regression are shown in Table 5.7, followed by analysis of the results.

Table 5.7. Autoregressive forecast model, January 2000 to December 2009

Variable	Coefficient	Standard Error	P-Value
Intercept	10.3880	3.1187	0.0012
FEB	-0.4419	0.3815	0.2494
MAR	-0.1240	0.5139	0.8097
APR	0.5046	0.5966	0.3996
MAY	0.8670	0.6493	0.1847
JUN	1.1392	0.6793	0.0965
JUL	1.0383	0.6896	0.1351
AUG	0.9162	0.6812	0.1815
SEP	1.3389	0.6534	0.0430
OCT	1.1526	0.6035	0.0589
NOV	0.5111	0.5246	0.3322
DEC	0.8294	0.3995	0.0403
T	0.0368	0.0385	0.3410
$P_{c, (t-1)}$	0.9158	0.0393	0.0001*
R-squared: 0.8756 Durbin-Watson=1.3669		F-statistic= 56.8774 Prob(F-stat)=0.0001*	

The AR model indicates that the previous period's Class III milk price is significant in explaining the present value of the Class III milk price. Seasonality also plays a significant role during certain months, September, October, and December, which indicate that during these months the price of Class III milk increases. This could be explained by the school phenomena which means that as students return to school and participate in the school lunch program, the demand for milk increases as part of the increases in school lunch participation. The estimated coefficients in the model (Table 5.7) were used to forecast over the time frame January 2010 to July 2012 as part of the ex-post analysis. The forecasted Class III milk price from the ex-post analysis are presented partially in Table 5.8 for the years 2009-2012; entirety of the predicted values from the forecast are included in Appendix B.

Table 5.8. Ex-post forecast of Class III milk price ($/cwt.) via an autoregressive model.

	2010	2011	2012
January	14.6609	15.1914	15.6259
February	14.3225	14.8413	15.2267
March	14.6450	15.1990	15.5409
April	15.2729	15.8347	16.1941
May	15.6694	16.2151	16.6244
June	15.9168	16.5026	16.9352
July	15.8875	16.3856	16.9215
August	15.7616	16.2877	
September	16.2848	16.7789	
October	16.1939	16.6160	
November	15.5692	16.0528	
December	16.0091	16.3856	

When compared to the actual Class III milk price over the time frame January 2000 to July 2012, there was a correlation of 0.6011. To find the R-squared of the forecast the correlation was squared, resulting in a coefficient of 0.3613. The R-squared was confirmed through a regression of the forecasted Class III milk price against the actual Class III milk price, from January 2000 to July 2012. These results are presented in Table 5.10. The R-squared of other models must be superior to this autoregressive model's R-squared of 0.3358.

Table 5.9. Ex-post autoregressive forecast regression against actual Class III milk price, January 2000 to July 2012

Variables	Coefficient	Standard Error	P-Value
Intercept	-2.0062	1.7463	0.2525
Forecasted Class III Milk Price ($/cwt.)	1.1553	0.1258	0.0001*
R-squared: 0.3613 Durbin-Watson = 0.2233		Prob. of F-stat = 0.0001* F-Stat(2,151) = 84.2850	

The interpretations of the coefficients within this model are similar to that of the ex-post. Seasonality and the trend still play a significant role in explaining the Class III milk price along with the lagged Class III milk price. This AR model will be used to forecast the price of Class III milk into July 2014, as seen in Table 5.10.

Table 5.10. Out-of-sample forecast of Class III milk price ($/cwt.) via an autoregressive model, August 2012 to July 2014

Date	2012	2013	2014
January		16.1670	16.3454
February		15.7835	15.9977
March		16.1782	16.3844
April		16.7704	17.0378
May		17.1135	17.4485
June		17.3831	17.7331
July		17.2683	17.8003
August	16.8475	17.1201	
September	17.3075	17.5944	
October	17.1461	17.4498	
November	16.5142	16.7978	
December	16.9095	17.2070	

These forecasted Class III milk prices are compared against the other models' forecasts in Section 5.7 via RMSE and a Diebold-Mariano test. The forecasts of the autoregressive model are presented graphically in Figure 5.2. The autoregressive model does not experience the same fluctuations that actually occurred over time in the Class III milk market .As a result the forecast from the autoregressive model will have a difficult time predicting volatility other than that which occurs with the seasonal ebbs and flows of the market. The results of this forecast indicate a Class III milk price of $16.30/cwt. to 17.80/cwt. over the next two years.

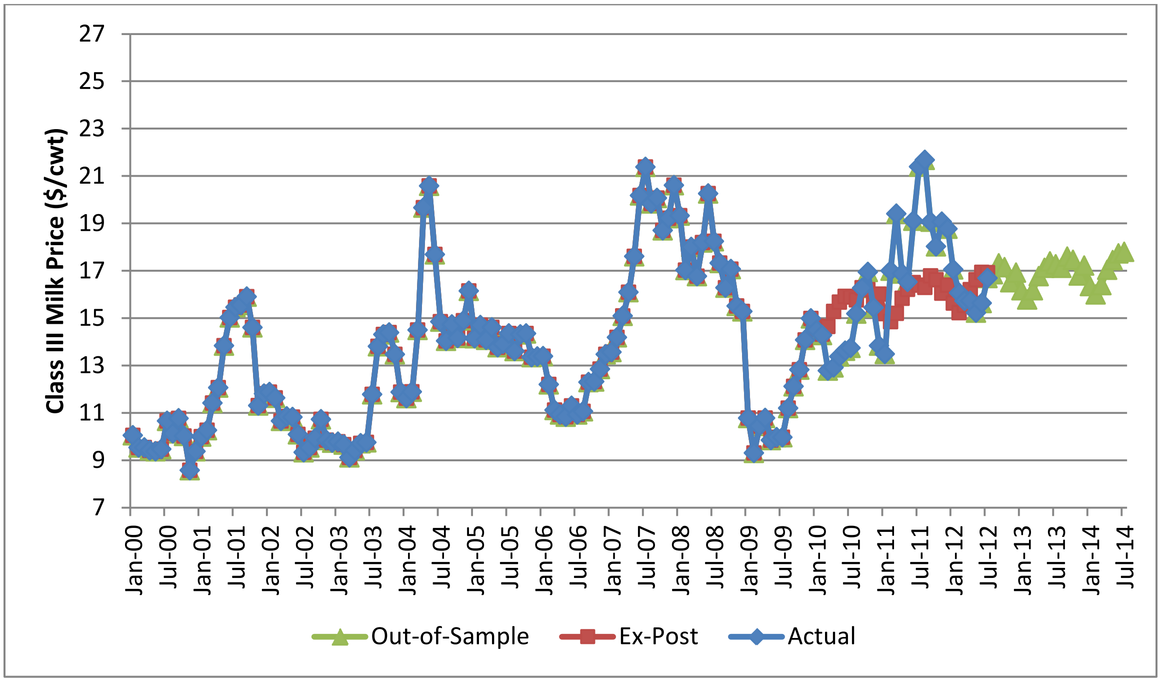

Figure 5.2. Autoregressive model ex-post and out-of-sample forecasts of Class III milk price, in addition to observed prices, Jan. 2000 to July 2014

5.4 Log of Consumption Results

The log of consumption model is a log-log model which reflects the influence of the percent change in consumption on the percent change in Class III milk prices, along with the influence of milk equivalent exports. The results of the log-log model over the time period of January 2000 to December 2009 are seen in Table 5.11.

Table 5.11. Log of consumption model, Jan. 2000 to Dec. 2009

Variables	Coefficient	Standard Error	P-Value
Intercept	3.6158	4.1888	0.3900
LNCONSD	-0.2212	0.6429	0.7314
EXP	0.0001*	0.0001*	0.0001*
FEB	-0.0664	0.0927	0.4753
MAR	-0.0740	0.0946	0.4358
APR	-0.0331	0.0860	0.7010
MAY	-0.0215	0.0900	0.8112
JUN	0.0151	0.0860	0.8608
JUL	0.0136	0.0858	0.8743
AUG	-0.0049	0.0944	0.9591
SEP	0.0721	0.0897	0.4231
OCT	0.0261	0.1014	0.7971
NOV	0.0074	0.0974	0.9394
DEC	0.0432	0.0906	0.6342
T	-0.0011	0.0015	0.4779
R-squared: 0.4212 Durbin-Watson = 0.2902		F-Stat(15,120)=5.4581 Prob. of F-stat = 0.0001*	

The R-squared of the model is 0.4212 with a significant F-statistic. This model also indicates that the inclusion of the autoregressive term would remove the presence of serial correlation, as shown by the D-W statistic.[6] However, it was determined that excluding the autoregressive term would allow the model to capture a larger part of the volatility occurring with the Class III milk price.

The model indicates that seasonality plays little role in determining the change in Class III milk price, and the coefficient of the trend variable is insignificant. The coefficient of the log of consumption shows that decreases in the production of milk cause an increase in Class III milk price. This follows economic logic that increases in Class III milk price causes decreases in the domestic consumption. However, this value is not significant. The significant parameter in this regression is the milk equivalent exports (*EXP*), which shows that as exports increase the Class

[6] The ex-post and out-of-sample models of the consumption based models are included in Appendix C. Models included in the Appendix will not be used to forecast prices of Class III milk.

III milk price also increases. Though this estimate is less than 0.0001, it is still statistically significant. The forecasted prices from this model as part of the ex-post analysis are in Table 5.12. The forecast occurred over the period January 2010 to July 2012. The complete report of the predicted values from January 2000 to July 2012 is seen in Appendix C.

Table 5.12. Ex-post forecast of Class III milk prices ($/cwt.) via a log of consumption model, August 2010 to July 2012

Date	2010	2011	2012
January	13.9471	14.2410	14.3478
February	13.5777	13.7693	13.8388
March	13.6749	14.1127	14.1852
April	14.2689	14.6732	14.8474
May	14.6848	15.0476	15.2326
June	14.9024	15.2812	15.4885
July	14.7840	15.1730	15.3535
August	14.7801	15.2015	
September	15.3650	15.8471	
October	15.2939	15.7006	
November	14.4640	14.8088	
December	14.9776	15.1974	

The forecasts from the ex-post log of consumption model have a correlation with the actual Class III milk price of 0.6305, which when squared indicates an R-squared of 0.3975. This is confirmed with a regression of the forecasted Class III milk price on the actual Class III milk price, as seen in Table 5.13.

Table 5.13. Ex-post log of consumption forecast regression against actual Class III milk price, January 2000 to July 2012

Variables	Coefficient	Standard Error	P-Value
Intercept	4.3295	0.9879	0.0001*
Forecasted Class III milk price ($/cwt.)	0.6736	0.0679	0.0001*
R-squared: 0.3975 Durbin-Watson = 0.2900	F-Stat(3,137)=98.3206 Prob. of F-stat = 0.0001*		

The R-squared of this regression is greater than the autoregressive forecast which is the minimum that all other forecast models must exceed to be suggested for use. It can be concluded that this model is superior to the autoregressive model in terms of its forecasting ability, and is capable of predicting a larger portion of the price volatility as hypothesized. The out-of-sample forecast was estimated for August 2012 to July 2014 based on the log of consumption model. The out-of-sample forecast is presented in the following table:

Table 5.14. Out-of-sample forecast of Class III milk price ($/cwt.) via a log of consumption model, August 2012 to April 2014

Date	2012	2013	2014
January		18.9786	19.3413
February		18.3019	19.5090
March		22.1000	25.8675
April		21.9958	23.3489
May		26.1187	29.9355
June		22.3423	23.5804
July		19.8922	20.9517
August	20.9660	24.0783	
September	19.2986	19.8579	
October	19.4877	21.7051	
November	20.3789	21.2965	
December	20.6949	22.2858	

The forecasted Class III milk price results are compared with the other models in Section 5.7. The graphical representation of all of ex-post and out-of-sample forecasts of the log of consumption model compared to the actual Class III milk price is seen in Figure 5.3.

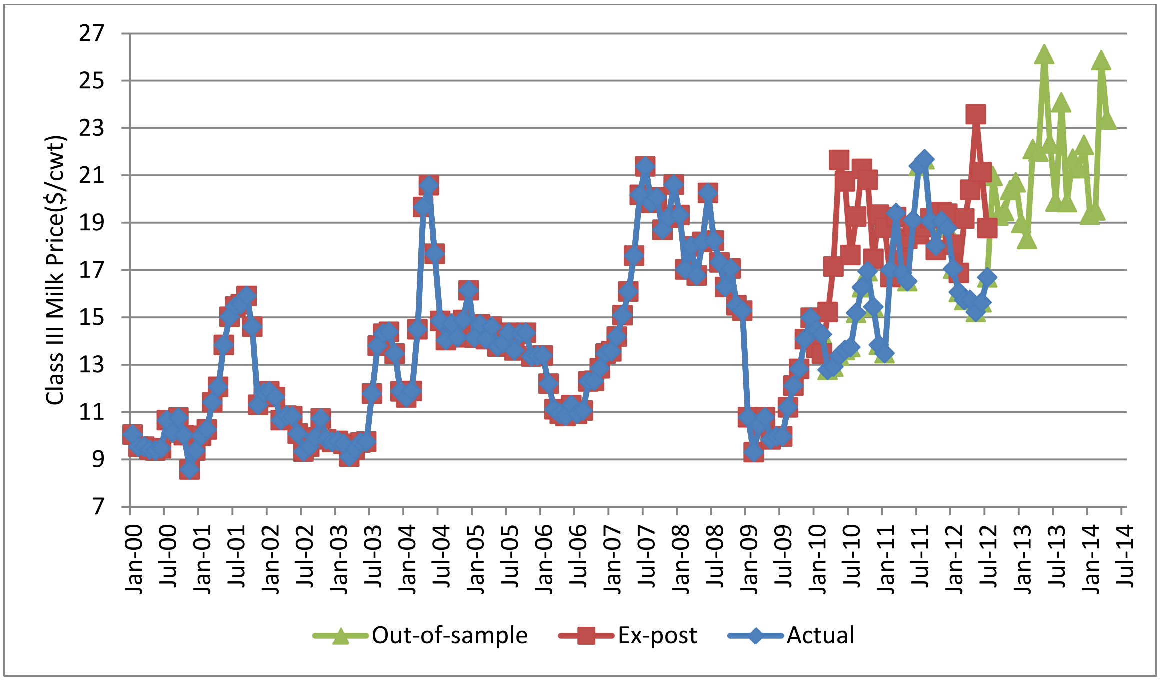

Figure 5.3. Log of consumption model ex-post and out-of-sample forecasts for Class III milk price, in addition to observed prices, January 2000 to July 2014

This figure illustrates that the ex-post and out-of-sample forecasts are influenced only slightly by a seasonal pattern, whereas the volatility that occurs within Class III milk prices is captured partially by this model. This model will be compared to other models to determine the best choice for a forecasting tool. This model indicates that prices will range from $18.85/cwt. to $29.00/cwt. from August 2012 to July 2014, with a more reasonable price forecast realized around $24.90/cwt. as the maximum price.

5.5 Vector Autoregression Results

The VAR model is concerned with the interactions of variables and their autoregressive terms to allow for a forecast. This model was constructed to be a simplistic explanation of the interactions which occur in the dairy market to determine the price of Class III milk. Class III milk was determined to interact with total milk production, milk equivalent imports and exports, cheese production, cheese storage, and a cumulative profit variable, along with exogenous variables, seasonality and trend. It is likely the forecast from this model will resemble the autoregressive model because this model is autoregressive in nature. An essential characteristic to note of a VAR model is the possibility of co-integration among the variables used to regress the VAR. Cointegration, as previously discussed, tests for the presence of a relationship between the variables over the long-run.

Section 5.5.1: Unrestricted Vector Autoregression

The VAR model was run initially without co-integration for both the ex-post and out-of-sample methods; the regression results are included in Appendix D. These non-cointegrated models are referred to as unrestricted VAR meaning that there exist no cointegrating equations to enforce relationships among the variables within the model. The unrestricted VAR model was used to conduct an ex-post forecast of Class III milk prices from January 2010 to July 2012 and the results are in Table 5.15; predicted values of the forecast are included in Appendix D.

Table 5.15. Ex-post forecast of Class III milk price ($/cwt.) via an unrestricted vector autoregression model, August 2010 to July 2012.

Date	2010	2011	2012
January	15.3208	15.6665	16.3982
February	14.8848	15.3113	15.9893
March	15.2597	15.7027	16.4603
April	15.9865	16.4628	17.2011
May	16.4326	16.9333	17.6579
June	16.7652	17.2995	18.0067
July	16.5618	17.1152	17.8458
August	16.5272	17.0099	
September	17.0151	17.4558	
October	16.8173	17.3540	
November	16.1240	16.7254	
December	16.4250	17.0950	

The results of the ex-post forecast from the unrestricted VAR are correlated with the actual Class III milk price by 0.5627 which translates to an R-squared of 0.3166, which is inferior to the autoregressive forecast model. This is confirmed through the regression of the ex-post forecasted Class III milk price on the actual prices (Table 5.16).

Table 5.16. Unrestricted vector autoregression ex-post forecast regressed against actual Class III milk price, January 2000 to July 2012

Variables	Coefficient	Standard Error	P-Value
Intercept	1.5555	1.5028	0.3023
Forecasted Class III Milk Price ($/cwt.)	0.8829	0.1063	0.0001*
R-squared: 0.3166 Durbin-Watson = 0.2025	F-Stat(3,137)=69.0290 Prob. of F-stat = 0.0001*		

The results of this regression indicate that this model's forecast of Class III milk price is inferior to the autoregressive results. This will be discussed in more detail in Section 5.7: Model Comparisons. Despite the lack of cointegration, this model will be compared with the other forecasts. The out-of sample forecast is presented in Table 5.17.

Table 5.17. Out-of-sample forecast of Class III milk price ($/cwt.) via the unrestricted vector autoregression model, August 2012 to July 2014

Date	2012	2013	2014
January		16.6801	17.3794
February		16.3479	16.9792
March		16.8401	17.3581
April		17.6706	18.0892
May		18.1539	18.4741
June		18.5279	18.7325
July		18.3102	18.4999
August	17.3632	18.1994	
September	17.8974	18.6382	
October	17.7960	18.5120	
November	17.1396	17.8748	
December	17.4608	18.2079	

Forecasted Class III milk prices are forecasted out from August 2012 to July 2014, a period of twenty-four months. These prices are illustrated graphically in a comparison of the ex-post the out-of-sample forecasted prices and the realized prices of Class III milk in Figure 5.4.

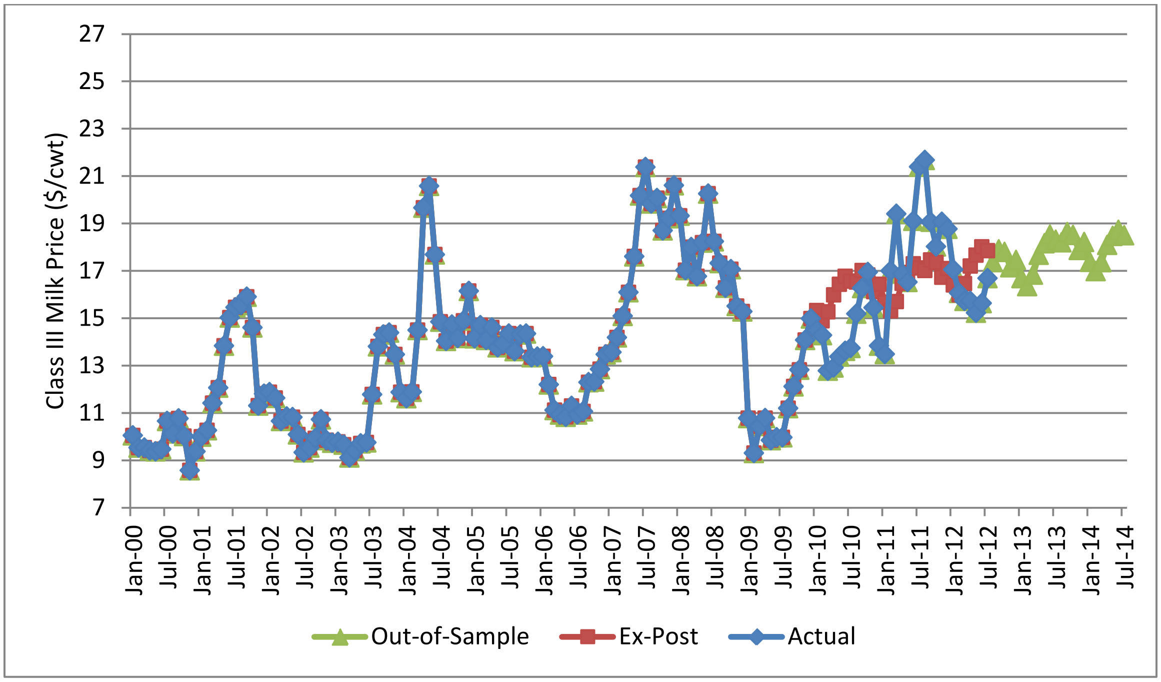

Figure 5.4. Unrestricted vector autoregression model ex-post and out-of-sample forecasts of Class III milk price, in addition to observed prices, January 2000 to July 2014

Graphical representation of the VAR ex-post and out-of-sample forecasts in comparison to the actual Class III milk price indicates that there is little change from the autoregressive model forecasts. A slight change is seen in the ability of the unrestricted VAR to respond to some of the fluctuation occurring with the actual Class III milk price in the beginning of the predicted values. The forecast indicates that the Class III milk price will range from $15.50/cwt. to $18.00/cwt. over the next two years.

Section 5.5.2: Restricted Vector Autoregression

An additional step of the VAR model was to examine cointegration among the endogenous variables. The Engle-Granger co-integration test of the group of variables was used to examine the data for a common relationship among the residuals. It was determined that co-integration is present within the model, and the results of the test are presented in Table 5.18.

Table 5.18. Engle Granger test for cointegration with in the vector autoregression model

Dependent	t-statistic	Prob.*	z-statistic	Prob.*
Class 3Milk Price	-4.9771	0.0662	-43.9747	0.0548
Cheese Storage	-1.8758	0.9938	-10.5132	0.9819
Total Milk Production	-2.3485	0.9720	-15.0663	0.9131
Exports	-16.9969	0.0001*	-214.1910	0.0001*
Imports	-3.0707	0.8251	-74.5275	0.0001
Total Cheese Production	-1.7148	0.9963	-6.1756	0.9984
12 Month Cumulative Profit	-2.5572	0.9487	84.1128	0.9999

The null hypothesis of the Engle-Granger test is that the series is not cointegrated. The tests suggest that co-integration exists between the endogenous variables used in the VAR. This conclusion needed to be furthered by determining the number of cointegrating equations using the Johansen Cointegration (Table 5.19).

Table 5.19. Johansen cointegration test for the vector autoregression models

Hypothesized # of Cointegrating Equations	Eigenvalue	Trace Statistic	0.05 Critical Value	P-Value
None *	0.5534	359.9387	125.6154	0.0000
At most 1 *	0.4948	226.9304	95.7537	0.0000
At most 2 *	0.2592	114.2665	69.8189	0.0000
At most 3 *	0.2206	64.7603	47.8561	0.0006
At most 4 *	0.0880	23.6372	29.7971	0.2162
At most 5	0.0498	8.4348	15.4947	0.4201
At most 6 *	0.0000	0.0004	3.8415	0.9848
Trace test indicates 4 cointegrating eqn(s) at the 0.05 level				

These results included in Table 5.19 tested for the number of cointegrating equations and found that there are four equations at the 0.05 level. The entirety of this test is included in Appendix D. The cointegrated VAR model is referred throughout remainder of this as a restricted VAR. The restricted VAR indicates that the Class III milk price is the poorest fit of all other endogenous variables in the VAR, with an R-Squared of 0.4256, though the non-cointegrated VAR has a higher R-squared for Class III milk (restricted and unrestricted VAR regression results are presented in Appendix D). However, cointegration is a necessary step because it compensates for statistical errors that can occur because of unaccounted for cointegration. The forecast of the restricted VAR is similar in the R-squared value to the unrestricted VAR model, despite the low R-squared of the Class III milk price endogenous variable; this will be discussed throughout the following. An ex-post forecast of the restricted VAR was performed based on the model estimated using the data over January 2000 to December 2009 (regression results are presented in Appendix D), with the forecast from January 2010 to July 2012 (Table 5.20); all predicted values of the restricted VAR are in Appendix D.

Table 5.20. Ex-post forecast of Class III milk price ($/cwt.), via the restricted vector autoregression ex-post model, August 2010 to July 2012

Date	2010	2011	2012
January	13.6366	14.4166	15.0904
February	13.2400	13.9751	14.5950
March	13.6985	14.4311	15.0706
April	14.4895	15.2157	15.8706
May	14.9636	15.6568	16.3455
June	15.2667	15.9804	16.6228
July	15.0536	15.7315	16.3565
August	14.9965	15.6484	
September	15.5641	16.1694	
October	15.5792	16.1294	
November	14.9892	15.6268	
December	15.2871	15.9676	

The forecasted results of the restricted VAR are correlated with the realized Class III milk prices with a correlation coefficient of 0.5738. The correlation coefficient squared is an R-squared term of 0.3292, which is confirmed in the regression of the forecasted Class III milk price against the actual prices (Table 5.21).

Table 5.21. Ex-post restricted vector autoregression ex-post forecast against actual Class III milk price, January 2000 to July 2012

Variables	Coefficient	Standard Error	P-Value
Intercept	4.0691	1.1711	0.0007
Forecasted Class III milk price ($/cwt.)	0.8186	0.0957	0.0001*
R-squared: 0.3292 Durbin-Watson = 0.2065	F-Stat(3,137)=73.1211 Prob. of F-stat = 0.0001*		

The forecasted results of the restricted VAR are superior to the unrestricted results, but it is inferior to both the autoregression models and the log of consumption model. The out-of-sample forecast based on the restricted VAR model is presented in Table 5.22; the predicted values of the forecast are included in Appendix D.

Table 5.22. Out-of-sample forecast of the Class III milk price ($/cwt.) from the restricted vector autoregression, August 2012 to July 2014

Date	2012	2013	2014
January		17.1030	17.8013
February		16.6778	17.3460
March		17.0781	17.8089
April		17.8518	18.6127
May		18.3056	19.0526
June		18.6232	19.3585
July		18.4425	19.1682
August	17.8112	18.3559	
September	18.2989	18.9498	
October	18.1827	18.8873	
November	17.5500	18.2994	
December	17.9795	18.6040	

The results of the restricted VAR Class III milk price forecast indicate that the price will range from $17.55/cwt. to $19.35/cwt. over the next twenty-four months. A graphical comparison of the ex-post and out-of-sample forecasts and the actual Class III milk price is seen in Figure 5.5.

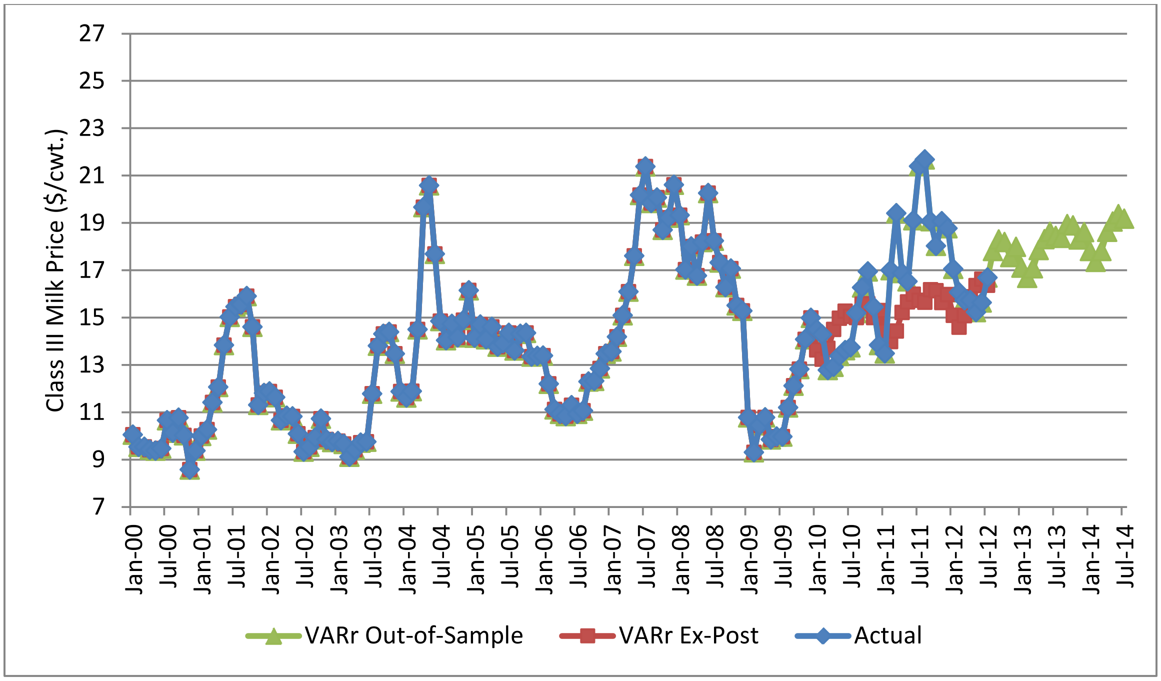

Figure 5.5. Restricted vector autoregression model ex-post and out-of-sample forecasts of Class III milk price, in addition to observed prices, Jan. 2000 to July 2014

As seen in Figure 5.5 the forecasted Class III milk price based on the restricted model also fluctuates seasonally like the autoregressive models. This supports the hypothesis that the VAR model would be similar to the AR model. The difference with the restricted VAR model is that the forecasted results are conditioned by other endogenous variables through the cointegrating equations; as a result the relationship between the endogenous variables is maintained throughout the forecast.

5.6 Partial Equilibrium Model

The initial step in the partial equilibrium model was to run a model using OLS. Because the OLS model is an over-identified system of equations, it will be biased an unable to estimate a forecast of the system equations. However, it will give an initial idea of how each of the individual equations in the system estimate. The OLS regression was initially estimated for this system of equations. It was determined that all equations were functional, though biased and unable to estimate a partial equilibrium model because the system was over-identified as discussed in Chapter 3: Methodology. In response to this, the system was re-estimated using both 2SLS and 3SLS to correct for bias and to estimate a partial equilibrium model through the use of the instrumental variables.

The initial step when choosing the instrumental variables for the 2SLS and 3SLS estimators was to look for correlation. The correlation coefficients between the chosen exogenous instrumental variables indicate that they are not perfectly correlated. The table of correlation coefficients can be found in Appendix E. The only variable of concern for high collinearity is the price index for machinery and fuel. However, the models were estimated including and excluding the variable and it was determined to continue to include this variable.

Section 5.6.1: Two Stage Least Squares Regression

The result of the 2SLS regression model estimated over January 2000 to December 2009 is presented in Appendix E. The ex-post forecast is presented in the following table for the time period January 2010 to July 2012.

Table 5.23. Ex-post forecast of the Class III milk price ($/cwt.) via the two stage least squares model, August 2010 to July 2012

Date	2010	2011	2012
January	15.8483	15.5432	16.1488
February	15.5104	15.5270	15.8782
March	15.5756	15.9823	16.0725
April	15.4231	16.2075	15.9358
May	15.7297	16.0896	16.1300
June	15.7279	15.9548	16.1099
July	15.7222	16.0375	15.9733
August	15.5915	16.0451	
September	15.5571	16.1336	
October	15.8443	15.9017	
November	15.5596	15.8022	
December	15.6084	15.8254	

The ex-post 2SLS model forecast results presented above in Table 5.23 are contrasted with the actual Class III milk price. The correlation coefficient between the actual and the forecasted price is 0.6420, which can be interpreted as an R-squared of 0.4122. The results of the regression of the forecasted values against the actual values are presented in Table 5.24.

Table 5.24. Ex-post two-stage least squares ex-post forecast against actual Class III milk price, January 2000 to July 2012

Variables	Coefficient	Standard Error	P-Value
Intercept	-3.8097	3.1830	0.2333
Forecasted Class III milk price ($/cwt.)	1.3044	0.2337	0.0001*
R-squared: 0.4122 Durbin-Watson = 0.2495	F-Stat(3,137)=104.47 Prob. of F-stat = 0.0001*		

The correlation coefficient is the highest of all models for the 2SLS however; the regression results show little volatility. The out-of-sample forecast is presented in Table 5.25. The results of this model are presented graphically in Figure 5.6. They suggest that the 2SLS is the least volatile of all price forecasts.

Table 5.25. Out-of-sample forecast of Class III milk price ($/cwt.) via the two stage least squares model, August 2012 to July 2014

Date	2012	2013	2014
January		16.4051	16.5320
February		16.2819	16.3449
March		16.3988	16.5198
April		16.3884	16.6420
May		16.6909	16.9828
June		16.5884	16.7674
July		16.6857	16.7301
August	16.2786	16.7175	
September	16.1373	16.4714	
October	16.2530	16.5347	
November	16.1968	16.3722	
December	16.2262	16.3768	

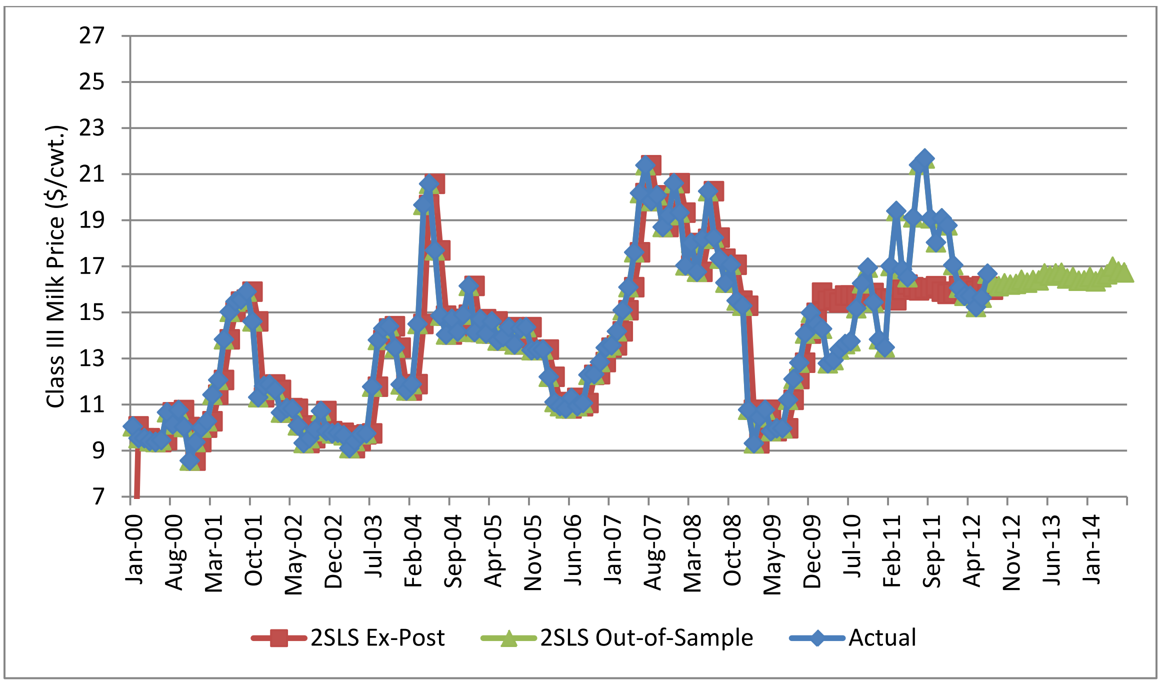

Figure 5.6. Two stage least squares ex-post and out-of-sample forecasts for Class III milk price, in addition to observed prices, January 2000 to July 2014

The forecasts of the 2SLS out-of-sample model indicate that the price of Class III milk futures will range from $16.20/cwt. to $16.95/cwt. As seen from Figure 5.6 there is little fluctuation that occurs within the forecasted results and because of this observation the forecasted prices from August 2012 through July 2014 are likely an inaccurate forecast. This will be discussed in more detail in Section 5.7.

Section 5.6.2: Three Stage Least Squares Regression

The result of three-stage least squares regression model is presented in Appendix E. These regression results were used to forecast both the ex-post and out-of-sample prices. The ex-post forecast is seen in Table 5.26.

Table 5.26. Ex-post forecast results of Class III milk price ($/cwt.) via the three stage least squares model, August 2010 to July 2012

Date	2010	2011	2012
January	14.7859	14.4124	14.6955
February	14.4997	14.4390	14.3973
March	14.3729	14.7305	14.4682
April	14.1973	14.9685	14.2595
May	14.4233	14.8590	14.3545
June	14.4574	14.7864	14.4029
July	14.5993	14.9111	14.3697
August	14.4245	14.9077	
September	14.4335	14.9181	
October	14.6275	14.7428	
November	14.4520	14.5482	
December	14.4549	14.4638	

These forecasted results of the Class III milk price have a correlation coefficient with the actual Class III milk price of 0.6006 which translates to an R-squared of 0.3607. This can be re-stated as the fit of the data from a regression of the forecasted Class III milk price on the actual Class III milk price. The results of this regression are presented in Table 5.27.

Table 5.27. Three-stage least squares ex-post forecast against actual Class III milk price, January 2000 to July 2012

Variables	Coefficient	Standard Error	P-Value
Intercept	-8.4736	2.4502	0.0007
Forecasted Class III milk price ($/cwt.)	1.6221	0.1769	0.0001*
R-squared: 0.3607 Durbin-Watson = 0.2318	F-Stat(3,137)=58.4103 Prob. of F-stat = 0.0001*		

The results of the regression indicate that this model is inferior to the 2SLS model because the R-squared of the forecasted data against the actual data is lower than that of the 2SLS model. The predictive power of this model will be compared to the VAR, AR, and log of consumption model in Section 5.7. The out-of-sample forecast from this model is presented in Table 5.28. The forecast results of the three stage least squares regression is presented graphically in Figure 5.7.

Table 5.28. Out-of-sample forecast results of Class III milk price ($/cwt.) via the three stage least squares model, august 2012 to July 2014

Date	2012	2013	2014
January		14.5322	14.6583
February		14.3803	14.5293
March		14.4069	14.4554
April		14.4408	14.5061
May		14.6072	14.7294
June		14.6021	14.5913
July		14.7059	14.7543
August	14.5185	14.6318	
September	14.5675	14.5386	
October	14.6202	14.6320	
November	14.4230	14.4961	
December	14.4457	14.4529	

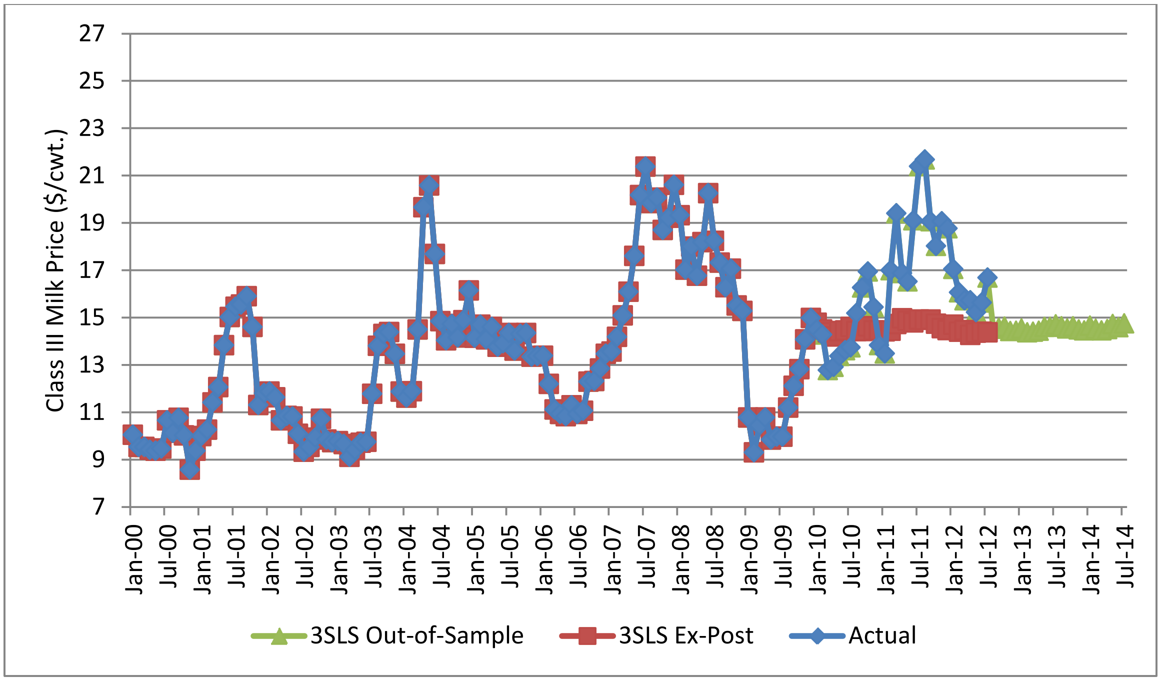

Figure 5.7. Three stage least squares ex-post and out-of-sample forecasts for Class III milk ($/cwt.), in addition to the observed prices, January 2000 to July 2014

The illustration of the Class III milk price for the actual prices and both the ex-post and out-of-sample forecasted prices indicate that this model does not adjust to the seasonality that can occur within the market as indicated by the autoregressive models. Furthermore, it also struggles to depict the volatility that occurs in the market. As a result this forecast is not a good choice for forecasting the Class III milk price from August 2012 to July 2014. This model indicates that the Class III milk price fluctuate between $14.20/cwt. to $14.95/cwt. from August 2012 to July 2014. This indicates that little fluctuation will occur in the Class III milk price which does not follow the conclusions that the 2012 drought will increase prices of feed and in turn increase Class III milk price.

5.7 Model Comparisons and Discussion

These past four sections have discussed the models which will be used to forecast Class III milk price through July 2014 based on data from January 2000 to December 2009. These models indicate the price of Class III milk price will stay in the $17.00/cwt. to $20.00/cwt. over the next twenty-four months. This conclusion supports those forecasts by the Livestock Marketing Information Center (LMIC) and also the USDA World Agricultural Supply and Demand Estimates (WASDE) report. The LMIC forecasts Class III milk price to be close to a record high of $19.75 to $21.25/cwt. in 2013 with prices remaining low at the end of 2012 (Farm and Dairy, 2012). The WASDE (2012) report indicates that prices from 2012 to 2013 will fluctuate around $16.70/cwt. to $18.65/cwt., which is more in line with the estimates of this thesis. The remainder of this chapter will discuss the model comparisons. The final section (Section 5.8) is concerned with determining the hedge horizon for which a dairy producer should participate in the futures market as part of risk management practices, based on realized feed costs.

Forecasting models were estimated and six forecasts were developed from the four methodologies. The six forecasts were based on the autoregressive model, the log of consumption model, the vector autoregression model, and the partial equilibrium model. Six forecasts were developed in result of the necessity of cointegration of the VAR model and two of the options for estimating a partial equilibrium model, 2SLS and 3SLS. The six forecasts of Class III milk price are compared with the actual observations of prices to determine a correlation coefficient; the R-squared value is the square of the correlation coefficient. Table 5.29 presents the correlation coefficient and R-squared results of the ex-post forecast and actual Class III milk prices occurring over January 2000 to July 2012.

Table 5.29. Class III milk price correlation coefficients of actual and forecasted data, Jan. 2000 to July 2012

Forecasted Class III Milk Price	Actual Class III Milk Price Correlation Coefficient	R-squared of actual and forecasted Class III milk price
Autoregressive Forecast	0.6011	0.3613
Log of Consumption Forecast	0.6305	0.3975
Unrestricted Vector Autoregression Forecast	0.5627	0.3166
Restricted Vector Autoregression Forecast	0.5738	0.3292
Two Stage Least Squares Forecast	0.6420	0.4122
Three Stage Least Squares Forecast	0.6006	0.3607

These reports indicate that the VAR model both unrestricted and restricted are the inferior models within the ex-post comparison of Class III milk prices, and that the partial equilibrium 2SLS model is the superior model along with the log of consumption model. The concern here is that although the 2SLS is the most correlated with the observed Class III milk price, there is little volatility captured by the model. Thus RMSE will be used to compare across models and also other industry forecasts to further the comparison of the ex-post forecasts. The results of the RMSE are seen in Table 5.30.

Table 5.30. Root mean square error of Class III milk price ($/cwt.) for ex-post analysis

Forecasted Class III Milk Price	Root Mean Square Error of Ex-Post Analysis
Autoregressive Forecast	2.1684
Log of Consumption Forecast	3.7627
Restricted Vector Autoregression Forecast	2.3661
Unrestricted Vector Autoregression Forecast	2.1680
Two Stage Least Squares Forecast	2.2745
Three Stage Least Squares Forecast	2.8176

RMSE was calculated using data from January 2010 through July 2012, a period of thirty-one months. Smaller RMSE calculations indicate a better forecast, because it is essentially a measure of the amount the price will differ from the actual price, in this case $/cwt. As seen in Table 5.30, the unrestricted VAR model is the best forecast of Class III milk price because the RMSE indicates that the forecasted price will differ by $2.1680/cwt. from the actual Class III milk price. Though these RMSE error terms are quite large, they are comparable to those values of RMSE calculated by Mosheim (2012). Research by Mosheim indicates an RMSE of 0.027, 0.028, 0.027, and 0.024 for the OLS, 2SLS, 3SLS and seemingly unrelated regression (SURE), respectively. However, these RMSE calculations are transformations of the All Milk Price from cwt. to a per lb. measurement, so the RMSE values of the unrestricted VAR, 2SLS, AR, and restricted VAR models are superior to the models developed in the research by Mosheim (2012). It must be noted that RMSE is not the entire story in the ex-post evaluation and it is important to remember that the unrestricted VAR has a higher explanatory power over the AR model and is better at predicting the price of Class III milk because it accounts for more conditioning variables. An interesting side note, is although the log of consumption model is a more volatile forecast, it is the poorest in its RMSE calculation.

The final step of comparing the models is to conduct a Diebold-Mariano test, which compares the significance of the out-of-sample forecasts between the various models. The results of the Diebold-Mariano test are presented in Table 5.34 and Table 5.35. Table 5.34 is the report of the Diebold-Mariano regression results associated with absolute loss. If the p-value is significant at the 95% confidence (meaning a p-value less than 0.05) then the forecast results of the two models are statistically significant from one another. The only regressions which are statistically significant in their results are the unrestricted and restricted VAR models, and the log of consumption and 2SLS models at the 95% confidence level. All of the results in the table can be compared to determine if the forecasts of the model are statistically different one from another.

Table 5.31. Diebold-Mariano test for statistical significance between model forecasts, using the absolute loss calculation

Forecast Model Comparisons		D-Absolute Loss		
		Coefficient	Standard Error	P-Value
Autoregressive	Log of Consumption	-0.05944	0.2577	0.0223
Autoregressive	Unrestricted Vector Autoregression	-0.1140	0.0484	0.0196
Autoregressive	Restricted Vector Autoregression	-0.1008	0.0428	0.0197
Autoregressive	Two-Stage Least Squares	-0.3245	0.1403	0.0291
Autoregressive	Three Stage Least Squares	-0.2965	0.1285	0.0220
Log of Consumption	Unrestricted Vector Autoregression	0.4804	0.2135	0.0257
Log of Consumption	Restricted Vector Autoregression	0.4936	0.2178	0.0246
Log of Consumption	Two-Stage Least Squares	0.2699	0.1361	0.0490
Log of Consumption	Three Stage Least Squares	0.2979	0.1465	0.0435
Unrestricted Vector Autoregression	Restricted Vector Autoregression	0.0132	0.0078	0.0931
Unrestricted Vector Autoregression	Two-Stage Least Squares	-0.2105	0.0989	0.0347
Unrestricted Vector Autoregression	Three Stage Least Squares	-0.1825	0.0875	0.0385
Restricted Vector Autoregression	Two-Stage Least Squares	-0.2237	0.1038	0.0325
Restricted Vector Autoregression	Three Stage Least Squares	-0.1957	0.0924	0.0357
Two-Stage Least Squares	Three Stage Least Squares	0.0280	0.0122	0.0227

Table 5.32 re-estimates the Diebold-Mariano test using the squared loss as the regressor. The results can be interpreted in the same way; if the p-value is less than 0.05, then the regression indicates that the forecast results of the two models are statistically significant from one another.

Table 5.32. Diebold-Mariano test for statistical significance between model forecasts, using the squared loss calculation

Forecast Model Comparisons		D-Squared Loss		
		Coefficient	Standard Error	P-Value
Autoregressive	Log of Consumption	-3.7023	1.8496	0.0469
Autoregressive	Unrestricted Vector Autoregression	-0.1486	0.0636	0.0207
Autoregressive	Restricted Vector Autoregression	-0.1247	0.0536	0.0212
Autoregressive	Two-Stage Least Squares	-1.0054	0.4708	0.0341
Autoregressive	Three Stage Least Squares	-0.8542	0.4037	0.0358
Log of Consumption	Unrestricted Vector Autoregression	3.5536	1.7993	0.0498
Log of Consumption	Restricted Vector Autoregression	3.5776	1.8035	0.0489
Log of Consumption	Two-Stage Least Squares	2.6969	1.5021	0.0743
Log of Consumption	Three Stage Least Squares	2.8481	1.5992	0.0695
Unrestricted Vector Autoregression	Restricted Vector Autoregression	0.0240	0.0151	0.1137
Unrestricted Vector Autoregression	Two-Stage Least Squares	-0.8568	0.4213	0.0435
Unrestricted Vector Autoregression	Three Stage Least Squares	-0.7056	0.3550	0.0485
Restricted Vector Autoregression	Two-Stage Least Squares	-0.8807	0.4292	0.0416
Restricted Vector Autoregression	Three Stage Least Squares	-0.7295	0.3632	0.0461
Two-Stage Least Squares	Three Stage Least Squares	0.1512	0.0699	0.0320

The results indicated above support the conclusions of the previous DM tests. Fewer models are statistically insignificant in their forecasts using the results in Table 5.32. The statistically insignificant forecasts as calculated by the squared loss calculation occur between all but the unrestricted and restricted VAR models, and the log of consumption and 2SLS models. The remaining models are statistically insignificant in their forecasts at the 95% confidence level. The following figure illustrates the results of all forecasts from the various models.

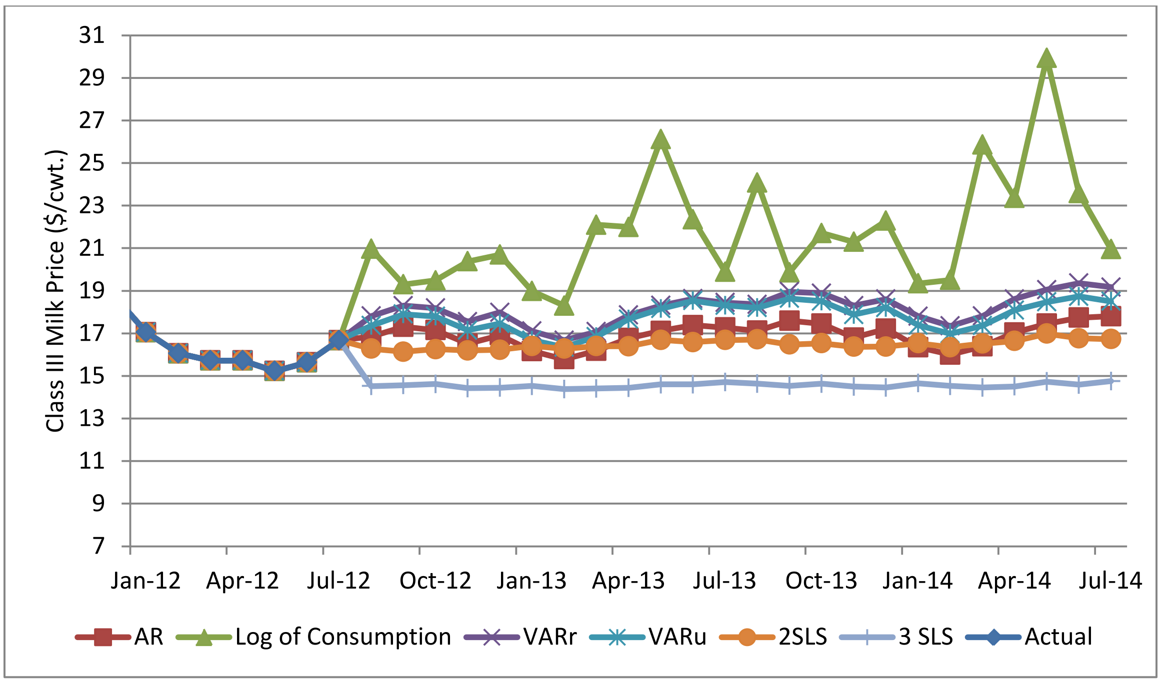

Figure 5.8. All model forecasts for Class III milk ($/cwt.), in addition to the observed prices, January 2012 to July 2014

From these conclusions stated above, the forecasts from the unrestricted and restricted VAR models, the log of consumption model, the 2SLS model, and the autoregressive model are suggested for use for forecasting Class III milk price through July 2014, the 3SLS model is ignored because it shows little movement in price. The ex-post analysis indicates that the unrestricted VAR is superior to all other estimates in terms of the RMSE calculation. The unrestricted VAR comes at the highest recommendation because it has the best ability of reflecting the changing dynamics in the industry, and it was the superior model within the ex-post analysis.

5.8 Hedging Analysis

Results determined in the previous sections suggest that the unrestricted VAR model is the best forecast using the ex-post methodology. Additionally, this forecast of Class III milk price ($/cwt.) was determined as statistically insignificant from those forecasts of the AR in both Diebold-Mariano tests. To continue this research it is necessary to determine the point at which an optimal hedge in the Class III milk futures should be conducted to lock in a profit margin. The intent of this section is to determine the hedging horizon of Class III milk futures. Methodology used in this section is based on the research by Koontz, Hudson, and Hughes (1992) where they regress the feed cost i months prior to delivery against the contract price i months prior to delivery. This model also includes an autoregressive term and is based on thirty-one observations over the future contracts of January 2010 to July 2012, with feed costs extending back twelve months. Regressions were estimated for $i = 0,1,\ldots 12$. The regression results are presented in Table 5.33.

Table 5.33. Regression results explaining Class III milk price futures ($/cwt.) with variable costs of feeding, January 2010 to July 2012.

Dependent Variable	Independent Variable	β_1	ρ	R-squared	Sigma	t-test 1[a]	t-test 2[b]
CP(t)	FC(t)	0.5588 (0.4533)[c]	0.7216 (0.1396)[c]	0.6709	1.4074	________	-7.0285 (0.0001*)[d]
CP(t-1)	FC(t-1)	0.6297 (0.4272)	0.7096 (0.1438)	0.6951	1.2037	1.3424 (0.0946)[d]	-5.7559 (0.0001*)
CP(t-2)	FC (t-2)	0.5542 (0.4398)	0.8064 (0.1376)	0.7638	0.9360	11.6093 (0.0001*)	2.0985 (0.9778)
CP(t-3)	FC (t-3)	0.5897 (0.3716)	0.7779 (0.1547)	0.7934	0.7594	11.5057 (0.0001*)	2.2799 (0.9851)
CP(t-4)	FC (t-4)	0.5431 (0.3068)	0.7572 (0.1483)	0.8385	0.5949	19.4572 (0.0001*)	3.5638 (0.9994)
CP(t-5)	FC (t-5)	0.3833 (0.3352)	0.8058 (0.1305)	0.8545	0.5281	2.3184 (0.0137)	-3.8713 (0.0003)
CP(t-6)	FC (t-6)	0.0268 (0.3761)	0.9320 (0.0865)	0.8655	0.4892	3.6950 (0.0004)	-2.4889 (0.0093)
CP(t-7)	FC (t-7)	0.0802 (0.3193)	0.9237 (0.0918)	0.8556	0.4564	5.3541 (0.0001*)	-1.0795 (0.1445)
CP(t-8)	FC (t-8)	0.0862 (0.3065)	0.9136 (0.1033)	0.8222	0.4515	6.4613 (0.0001*)	-0.4853 (0.3155)
CP(t-9)	FC (t-9)	0.1870 (0.2383)	0.8809 (0.1095)	0.8270	0.3928	7.0285 (0.0001*)	________
CP(t-10)	FC (t-10)	0.4295 (0.1506)	0.7763 (0.1282)	0.8338	0.3364	7.5788 (0.0001*)	0.4578 (0.6748)
CP(t-11)	FC (t-11)	0.4536 (0.1098)	0.5893 (0.1401)	0.7733	0.3274	7.6652 (0.0001*)	0.4553 (0.6739)
CP(t-12)	FC (t-12)	0.3862 (0.1018)	0.6092 (0.1014)	0.7996	0.2665	9.1712 (0.0001*)	1.2690 (0.8929)

[a] Statistic for the one-tailed test of whether or not the error variance of the model with CP(t) as the dependent variable is greater than the error-variance of the remaining models.
[b] Statistic for the one-tailed test of whether or not the error variance of the model with CP(t-9) is smaller than the error variance of the remaining models.
[c] Standard errors are in parentheses under parameter estimates
[d]P-values are in parentheses under test statistics.

The regressions presented in Table 5.33 are specified where *CP* is the contract price and *FC* is the variable feed cost in time *t-i*, where *t* is the month of contract expiration and *i* represents those months remaining until contract expiration occurs. β_1 serves as the coefficient of the *FC* variable. The autoregressive component of this regression is represented by ρ. The R-squared is the explanatory power of the regressions and sigma is the standard error of the individual regressions.

A test of significance was involved in the comparison of these regressions to determine if the standard errors of the regressions varied from one another. There were two tests of significance involved, the first tested if the standard error of the first regression (*CP(t)*) was statistically greater than the standard error of all other regressions (t-test 1[a]). The null hypothesis of this test is presented in the following equation:

(29) $H_0 : \sigma_0^2 > \sigma_i^2 \ for \ i = 1, \dots, 12$

The second t-test examined if the standard error nine-months prior to expiration (*t-9*) was statistically less than the standard errors of all other regressions (t-test 2[b]). Nine months prior to expiration was chosen as the comparison for the second test because nine-months prior to expiration is when reproductive decisions are made and then after nine months gestation the resulting milk production occurs. This is based on the assumption that the feed costs are locked in from nine months prior to parturition, thus the beginning of milk production. The null hypothesis is presented in the following equation:

(30) $H_0 : \sigma_9^2 > \sigma_i^2 \ for \ i = 1, \dots 8 \ \ 10, 11, and \ 12$

These t-tests examine the error variance between models, though typically this is done using an F-test however, that test requires independence of the random variables involved in the models, which is not the case between these models. As a result a different calculation of the t-statistic must be used to accurately compare the error variances of the models (Cox and Hinkley, 1974). The t-test is calculated using the residuals of the regressions. A typical F-test assumes that the errors of *CP(t)* and *CP(t-i)* have a covariance coefficient (ρ) equal to zero. However, in this case ρ is greater than zero. This t-test uses the residuals of each regression to calculate the t-statistic. This t-statistic is referred to as *R*, and is calculated in the following:

(31) $$V_i = \sqrt{k_0}X_i + Y_i,$$

$$W_i = \sqrt{k_0}X_i - Y_i,$$

$$R = \sum_{i=1}^{n} V_i W_i \Big/ \sqrt{\left(\sum_{i=1}^{n} {V_i}^2 {W_i}^2\right)},$$

$$t - statistic = R\sqrt{N-1} \Big/ \sqrt{(1-R^2)} \sim t_{n-1=df}\ under\ H_0.$$

The above calculations determine the t-statistic, where V_i is the vector of residuals from regression *CP(t)* and where W_i is the vector of residuals from *CP(t-i)*. These are used to calculate the R-value which is in turn used to calculate the t-statistic. The t-statistic can be used to compare the error variances of the regressions and determine if the regressions are statistically different.

The results shown in Table 5.33 indicate that there is no strong relationship between the futures contract prices and the feed costs. However, there is some indication that the close-up months' contract prices (one to four months prior to expiration) reflect the feed costs more than all other months prior to expiration. This time period is the best month for industry participants to practice risk management behavior through the futures market, based on feed costs. This is indicated by the β coefficient statistically insignificant from 1 for all other months prior to contract expiration. The results of this analysis indicate that the Class III milk price futures are not strong reflections of the feed costs observed i months prior to contract expiration. This is a possible result of few producers participating in the Class III milk futures market, and leaving the major participation for wholesalers and retailers involved in the Class III milk and cheese market. Where in contrast the research this analysis is based on uses lean hog and cattle futures which have more participation from producers in their respective futures market. Thus, it could be inferred that feed prices play more of a role in determining futures price when producers participate more frequently in the futures market.

Further research could indicate a different variable which the Class III milk futures price reflects more accurately. It can be hypothesized that this factor would be more involved with the retail and wholesale levels of the market, ignoring the feed cost of the producers. Another note concerning this model is that six to eight months prior to contract expiration the future contract price is a reflection of the price from the previous month, meaning during this time there is little movement in the price of the futures contract. It is also important to note that during the contract expiration month and one month previous the market is at the most volatile. An additional implication of this model is that the futures prices are potentially a constant reflection of current market conditions and at no point strongly reflect the costs incurred by producers or other participants in the industry.

CHAPTER 6: CONCLUSIONS AND IMPLICATIONS

Class III milk price is a volatile component within the dairy industry, with many price changes occurring that are unexpected as well as disliked within the market. The volatility of the price is extreme and as a result many producers, wholesalers, and retailers involved in the Class III milk and cheese markets are deterred from participating in risk management decisions requiring the futures market. The intent of this research is to forecast Class III milk price through multiple models and determine the best forecast through both ex-post and out-of-sample analysis. The forecasted Class III milk price would improve expectations of changes in the volatility of the market and aid producers, wholesalers, and retailers in price risk management decisions.

The results of this thesis found that the unrestricted VAR model is the best forecast in both the ex-post and out-of-sample methods, with the log of consumption forecast statistically insignificant in its forecast as indicated by the squared loss function of the Diebold-Mariano test. An important note about the log of consumption model is although it is statistically insignificant from the unrestricted VAR model and it demonstrates more volatility than other models, it has the highest RMSE. Other relevant forecasts are the AR and restricted VAR model, along with the 2SLS model. The 2SLS model captures price movement of Class III milk associated with various changes in the entire dairy industry.

The unrestricted VAR model indicates that the price of Class III milk will range from $17.15/cwt. to $18.75/cwt. over the next two years. The log of consumption model indicates the price will move higher with the forecast indicating a Class III milk price of $18.85/cwt. to $29.00/cwt. However, a more reasonable adjustment (as calculated from the standard errors of the forecast) of this forecast would indicate that the price would have a maximum around $24.90/cwt. Other forecasts from the 2SLS, restricted VAR, and AR forecasts indicate a Class III milk price from $17.00/cwt. to $18.00/cwt. This is a slightly lower forecast of Class III milk and current market conditions as a result of the drought which occurred in the summer of 2012 indicate the price will rise higher.

The log of consumption model was the only approach by which volatility was observed in the Class III milk price forecast. Through comparisons of this model excluding and including the milk equivalent exports variable it was determined that exports play a major role in the volatility of Class III milk prices. The export market absorbs about 13.3% of the dairy production occurring in the U.S. and as a result when this market disappears large changes are seen in the Class III milk price (U.S. Dairy Export Council, 2011). Thus, it is concluded that a major contributor to the volatility in the Class III milk price is the exports of all dairy products. Other contributing factors are the realized profits associated with feed costs and milk prices, the total supply of milk, and the consumption of cheese.

The final component of this thesis was to determine an appropriate hedging horizon for Class III milk price futures. This analysis found that the Class III milk price futures were not a strong reflection of feed costs through the majority of contract life. There is some indication that one to four months prior to contract expiration the price of the futures contract is related more strongly to feed costs. This is indicated by the coefficient estimate of feed cost and the standard error. However, there is no point during contract life that there is a strong indication of a one to one relationship between feed cost and contract price, thus some other variable with more relation to the wholesale and consumer side of the market may be a larger determinant of the futures price. It is recommended that producers base hedging decisions involving the futures price on their current and expected price of feed if hedging one to four months prior to expiration, and manage their risk by locking in a margin at some point before contract expiration. It should also be noted that six to eight months prior to contract expiration there is little movement in the futures price. This is a possible result of low volume in the market.

As with all price forecasts there is always the opportunity to include additional variables within the model to predict price more accurately, however, a vital consideration is when a model is sufficient for forecasting and no more variables need be included. In these forecasting models there are some opportunities to include other aspects of the industry. A variable which was not noted in this study is to include the impact of niche dairy goods, such as organics, on the price of Class III milk. Two additional variables which could prove relevant to the forecasting capability of these models are to address the impact of labor availability in the farm level of the industry and the ability of producers to access capital for expansion. In relation to reflecting the producers' ability to access capital, is the problem of modeling herd inventories. A more detailed approach should be taken to observe the modeling of the cow inventories model associated with herd liquidation and herd expansion. It is clear from current market reports that the price of a cull cow is at an all-time high and it would prove valuable to see if a structural change has occurred in the dairy herd inventories associated with the rising cull cow prices.

Another opportunity to further this research is to readdress the profit variable with various dairy rations used throughout the country and expand the Class III milk price forecasts to a regional analysis based on estimated ration costs in these regions. The profit variable can also be extended to look at all variable costs associated with milk production. It was assumed within this model that all variable costs would move in accordance with the feed cost and would be captured implicitly in the regression within the intercept term.

The final aspect by which this thesis may be furthered is determining the variable to which the Class III milk price futures are more closely related, to allow the determination of a hedging horizon for market participants. This can be approached by comparing variables which measure the consumption of Class III milk related products and the exports of dairy products, or another consumption driven variable.

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APPENDIX A

Results of the Cow Inventory and Milk Production per Cow Regressions for various financial components

Table A.1. Cow inventory regression feed cost (ARFJA), Jan. 2000 to Dec. 2009

Variables	Coefficient	Standard Error	P-Value
Intercept	-20.0491	16.1766	0.2182
CULLD	-0.0001	0.0001	0.0549
CULLD(1)	-0.0002	0.0001	0.0062
CULLD(2)	-0.0002	0.0001	0.0070
REPD(3)	0.0002	0.0001	0.1414
FC (Feed Cost) ARFJA	0.0103	0.0750	0.8907
Feb	1.8289	4.3274	0.6735
Mar	6.2937	4.9450	0.2062
Apr	0.3458	5.7474	0.9522
May	38.0345	22.0940	0.0884
Jun	31.5550	21.2359	0.1406
Jul	29.1751	21.8718	0.1854
Aug	33.3239	21.5137	0.1247
Sep	34.0594	21.8833	0.1229
Oct	33.6027	21.4919	0.1212
Nov	6.0750	4.7742	0.2063
Dec	9.5397	3.8249	0.0143
Trend	-0.0429	0.1418	0.7629
INV(1)	0.7067	0.0759	0.0001*
R-squared: 0.5909 Durbin-Watson = 2.1403		F-Stat(19,115) = 7.7042 Prob. of F-stat = 0.0001*	

Table A.2. Cow inventory regression feed cost (Robinson), Jan. 2000 to Dec. 2009

Variables	Coefficient	Standard Error	P-Value
Intercept	-34.4520	18.8564	0.0708
CULLD	-0.0001	0.0001	0.0536
CULLD(1)	-0.0002	0.0001	0.0059
CULLD(2)	-0.0002	0.0001	0.0071
REPD(3)	0.0002	0.0001	0.0909
FC (Feed Cost) Robinson	0.1985	0.1791	0.2705
Feb	3.3540	4.4484	0.4527
Mar	5.9913	4.9204	0.2263
Apr	0.1550	5.7096	0.9784
May	40.7296	21.9381	0.0664
Jun	35.0476	21.1415	0.1006
Jul	32.5993	21.7299	0.1368
Aug	37.1303	21.3492	0.0852
Sep	38.6610	21.7420	0.0785
Oct	37.9545	21.3191	0.0782
Nov	6.5502	4.7165	0.1681
Dec	9.5224	3.8075	0.0141
Trend	-0.1396	0.1363	0.3082
INV(1)	0.6995	0.0761	0.0001*
R-squared: 0.5960 Durbin-Watson = 2.1461		F-Stat(19,115)=7.8675 Prob. of F-stat= 0.0001*	

Table A.3. Cow inventory regression profit (ARFJA), Jan. 2000 to Dec. 2009

Variables	Coefficient	Standard Error	P-Value
Intercept	-19.4886	12.4276	0.1201
CULLD	-0.0001	0.0001	0.0877
CULLD(1)	-0.0002	0.0001	0.0127
CULLD(2)	-0.0002	0.0001	0.0107
REPD(3)	0.0002	0.0001	0.1486
PRF ARFJA	0.0159	0.0427	0.7107
Feb	1.9630	4.2884	0.6482
Mar	6.5354	4.9672	0.1914
Apr	0.4954	5.7483	0.9315
May	37.3986	22.0406	0.0930
Jun	30.9189	21.1050	0.1462
Jul	28.3615	21.7710	0.1958
Aug	32.2285	21.4145	0.1356
Sep	32.7825	21.7141	0.1344
Oct	32.2590	21.3702	0.1344
Nov	5.8667	4.7209	0.2170
Dec	9.3663	3.8520	0.0169
Trend	-0.0179	0.0931	0.8477
INV(1)	0.6901	0.0779	0.0001*
R-squared: 0.5912 Durbin-Watson = 2.1210		F-Stat(19,115)=7.7135 Prob. of F-stat= 0.0001*	

Table A.4. Cow inventory regression profit (Robinson), Jan. 2000 to Dec. 2009

Variables	Coefficient	Standard Error	P-Value
Intercept	-19.2159	13.0299	0.1436
CULLD	-0.0001	0.0001	0.0724
CULLD(1)	-0.0002	0.0001	0.0101
CULLD(2)	-0.0002	0.0001	0.0089
REPD(3)	0.0002	0.0001	0.1422
PRF Robinson	0.0052	0.0472	0.9122
Feb	1.8050	4.3389	0.6783
Mar	6.3883	4.9562	0.2005
Apr	0.4045	5.7491	0.9441
May	37.6606	21.9702	0.0897
Jun	31.1531	21.0441	0.1420
Jul	28.7114	21.6868	0.1887
Aug	32.7459	21.2812	0.1272
Sep	33.3843	21.5431	0.1245
Oct	32.9142	21.1814	0.1235
Nov	5.9739	4.7174	0.2085
Dec	9.4794	3.8346	0.0152
Trend	-0.0293	0.0941	0.7560
INV(1)	0.7019	0.0772	0.0001*
R-squared: 0.5909 Durbin-Watson = 2.1340		F-Stat(19,115)=7.7025 Prob. of F-stat= 0.0001*	

Table A.5. Cow inventory 3 month cumulative profit (ARFJA), Jan. 2000 to Dec. 2009

Variables	Coefficient	Standard Error	P-Value
Intercept	-22.9521	11.1476	0.0422
CULLD	-0.0001	0.0001	0.1102
CULLD(1)	-0.0002	0.0001	0.0238
CULLD(2)	-0.0001	0.0001	0.0275
REPD(3)	0.0002	0.0001	0.1862
PRF3 ARFJA	0.0375	0.0144	0.0106
Feb	2.2330	4.2873	0.6037
Mar	7.6741	4.9018	0.1207
Apr	1.7370	5.5969	0.7570
May	33.6394	21.1257	0.1146
Jun	27.6036	20.1807	0.1746
Jul	24.3946	20.7784	0.2433
Aug	27.9310	20.3780	0.1737
Sep	28.0045	20.6858	0.1790
Oct	27.1844	20.3712	0.1852
Nov	4.8134	4.6604	0.3043
Dec	8.4971	3.8792	0.0309
Trend	0.0371	0.0705	0.5998
INV(1)	0.5941	0.0853	0.0001*
R-squared: 0.6094 Durbin-Watson = 2.0112		F-Stat(19,115)=8.3215 Prob. of F-stat= 0.0001*	

Table A.6. Cow inventory 3 month cumulative profit (Robinson), Jan. 2000 to Dec. 2009

Variables	Coefficient	Standard Error	P-Value
Intercept	-31.4591	11.2256	0.0061
CULLD	-0.0001	0.0001	0.1128
CULLD(1)	-0.0002	0.0001	0.0245
CULLD(2)	-0.0001	0.0001	0.0293
REPD(3)	0.0002	0.0001	0.0997
PRF3 Robinson	0.0431	0.0148	0.0045
Feb	2.1404	4.3128	0.6208
Mar	7.5479	4.8921	0.1262
Apr	1.5098	5.5624	0.7866
May	38.6648	20.5901	0.0634
Jun	32.2830	19.6770	0.1041
Jul	29.2218	20.2262	0.1518
Aug	32.9214	19.7999	0.0996
Sep	33.4343	20.0664	0.0989
Oct	32.8194	19.7316	0.0995
Nov	5.0427	4.6496	0.2808
Dec	8.5489	3.8956	0.0306
Trend	-0.0625	0.0646	0.3353
INV(1)	0.5699	0.0874	0.0001*
R-squared: 0.6116 Durbin-Watson = 1.9930		F-Stat(19,115)=8.3989 Prob. of F-stat= 0.0001*	

Table A.7. Cow inventory 6 month cumulative profit (ARFJA), Jan. 2000 to Dec. 2009

Variables	Coefficient	Standard Error	P-Value
Intercept	-26.5024	10.0343	0.0096
CULLD	-0.0001	0.0001	0.1297
CULLD(1)	-0.0002	0.0001	0.0173
CULLD(2)	-0.0001	0.0001	0.0159
REPD(3)	0.0002	0.0001	0.1642
PRF6 ARFJA	0.0298	0.0065	0.0001*
Feb	2.7571	4.2257	0.5157
Mar	7.8092	4.7068	0.1003
Apr	2.4899	5.3096	0.6402
May	34.1866	19.3298	0.0801
Jun	28.3739	18.4450	0.1273
Jul	24.9867	18.9392	0.1902
Aug	28.0005	18.5629	0.1347
Sep	28.0821	18.8425	0.1394
Oct	27.2883	18.5467	0.1445
Nov	5.8925	4.4676	0.1903
Dec	9.3882	3.7960	0.0151
Trend	0.0624	0.0562	0.2694
INV(1)	0.5139	0.0913	0.0001*
R-squared: 0.6434 Durbin-Watson = 2.0078		F-Stat(19,115)=9.6221 Prob. of F-stat= 0.0001*	

Table A.8. Cow inventory 6 month cumulative profit (Robinson), Jan. 2000 to Dec. 2009

Variables	Coefficient	Standard Error	P-Value
Intercept	-39.7610	10.0195	0.0001
CULLD	-0.0001	0.0001	0.1474
CULLD(1)	-0.0002	0.0001	0.0205
CULLD(2)	-0.0001	0.0001	0.0193
REPD(3)	0.0002	0.0001	0.0533
PRF6 Robinson	0.0343	0.0068	0.0001*
Feb	2.8848	4.2380	0.4977
Mar	7.8941	4.6746	0.0945
Apr	2.3349	5.2416	0.6570
May	42.4211	18.5961	0.0247
Jun	35.9383	17.7509	0.0457
Jul	32.6429	18.2041	0.0761
Aug	35.1969	17.8330	0.0513
Sep	35.6661	18.0934	0.0516
Oct	34.9560	17.7997	0.0524
Nov	5.4513	4.4322	0.2217
Dec	9.1308	3.7987	0.0182
Trend	-0.0939	0.0518	0.0732
INV(1)	0.4827	0.0930	0.0001*
R-squared: 0.6499 Durbin-Watson = 2.0024		F-Stat(19,115)=9.9015 Prob. of F-stat= 0.0001*	

Table A.9. Cow inventory 9 month cumulative profit (ARFJA), Jan. 2000 to Dec. 2009

Variables	Coefficient	Standard Error	P-Value
Intercept	-28.7257	9.5133	0.0032
CULLD	-0.0001	0.0001	0.0825
CULLD(1)	-0.0002	0.0001	0.0089
CULLD(2)	-0.0002	0.0001	0.0100
REPD(3)	0.0002	0.0001	0.0905
PRF9 ARFJA	0.0220	0.0041	0.0001*
Feb	2.1848	4.2664	0.6098
Mar	7.1223	4.6708	0.1306
Apr	1.2780	5.2103	0.8068
May	37.2969	18.3778	0.0452
Jun	31.3167	17.5192	0.0770
Jul	28.9126	17.9431	0.1104
Aug	32.6542	17.5591	0.0660
Sep	33.1848	17.8184	0.0656
Oct	32.2901	17.5449	0.0688
Nov	6.2665	4.4349	0.1609
Dec	9.5619	3.8248	0.0141
Trend	0.0563	0.0493	0.2565
INV(1)	0.4585	0.0927	0.0001*
R-squared: 0.6511 Durbin-Watson = 1.9602		F-Stat(19,115)=9.9508 Prob. of F-stat= 0.0001*	

Table A.10. Cow inventory 9 month cumulative profit (Robinson), Jan. 2000 to Dec. 2009

Variables	Coefficient	Standard Error	P-Value
Intercept	-41.8063	9.9734	0.0001
CULLD	-0.0001	0.0001	0.0783
CULLD(1)	-0.0002	0.0001	0.0084
CULLD(2)	-0.0002	0.0001	0.0102
REPD(3)	0.0002	0.0001	0.0385
PRF9 Robinson	0.0246	0.0047	0.0001*
Feb	2.3344	4.2743	0.5862
Mar	7.4054	4.6886	0.1175
Apr	1.5374	5.2354	0.7697
May	44.1895	18.3357	0.0179
Jun	37.5230	17.4922	0.0345
Jul	35.1434	17.9266	0.0528
Aug	38.6595	17.5494	0.0300
Sep	39.4035	17.8050	0.0293
Oct	38.5726	17.5230	0.0301
Nov	5.9450	4.4497	0.1847
Dec	9.3464	3.8320	0.0166
Trend	-0.1117	0.0513	0.0321
INV(1)	0.4646	0.0920	0.0001*
R-squared: 0.6481 Durbin-Watson = 1.9727		F-Stat(19,115)=9.8217 Prob. of F-stat= 0.0001*	

Table A.11. Cow inventory 15 month cumulative profit (ARFJA), Jan. 2000 to Dec. 2009

Variables	Coefficient	Standard Error	P-Value
Intercept	-27.3396	8.6895	0.0022
CULLD	-0.0001	0.0001	0.0525
CULLD(1)	-0.0002	0.0001	0.0028
CULLD(2)	-0.0002	0.0001	0.0035
REPD(3)	0.0002	0.0001	0.1211
PRF15 ARFJA	0.0175	0.0026	0.0001*
Feb	1.9596	4.2491	0.6457
Mar	6.3003	4.5422	0.1686
Apr	0.0751	4.9984	0.9880
May	31.4376	17.0861	0.0689
Jun	24.9058	16.2961	0.1297
Jul	22.5306	16.6667	0.1796
Aug	26.8935	16.2939	0.1021
Sep	27.7250	16.5349	0.0968
Oct	27.3939	16.2728	0.0955
Nov	6.2280	4.3042	0.1512
Dec	9.9722	3.7968	0.0100
Trend	0.0465	0.0412	0.2622
INV(1)	0.3827	0.0952	0.0001
R-squared: 0.6738 Durbin-Watson = 1.9326		F-Stat(19,115)=11.0152 Prob. of F-stat= 0.0001*	

Table A.12. Cow inventory 15 month cumulative profit (Robinson), Jan. 2000 to Dec. 2009

Variables	Coefficient	Standard Error	P-Value
Intercept	-41.7625	10.3865	0.0001
CULLD	-0.0001	0.0001	0.0501
CULLD(1)	-0.0002	0.0001	0.0036
CULLD(2)	-0.0002	0.0001	0.0044
REPD(3)	0.0002	0.0001	0.0940
PRF15 Robinson	0.0189	0.0039	0.0001*
Feb	1.7483	4.2376	0.6808
Mar	6.1387	4.6974	0.1944
Apr	-0.1229	5.2760	0.9815
May	36.2247	18.9542	0.0590
Jun	29.3060	18.1087	0.1089
Jul	27.0731	18.5628	0.1480
Aug	31.5265	18.1541	0.0857
Sep	32.5618	18.3972	0.0799
Oct	32.3173	18.0891	0.0772
Nov	6.1697	4.4631	0.1701
Dec	9.8520	3.8119	0.0113
Trend	-0.1645	0.0597	0.0070
INV(1)	0.4974	0.0894	0.0001*
R-squared: 0.6449 Durbin-Watson = 1.9992		F-Stat(19,115)=9.6867 Prob. of F-stat= 0.0001*	

Table A.13. Cow inventory 18 month cumulative profit (ARFJA), Jan. 2000 to Dec. 2009

Variables	Coefficient	Standard Error	P-Value
Intercept	-29.3756	8.8161	0.0012
CULLD	-0.0001	0.0001	0.0318
CULLD(1)	-0.0002	0.0001	0.0014
CULLD(2)	-0.0002	0.0001	0.0017
REPD(3)	0.0002	0.0001	0.0952
PRF18 ARFJA	0.0162	0.0025	0.0001*
Feb	1.9470	4.2231	0.6458
Mar	6.5055	4.5410	0.1552
Apr	0.1843	5.0114	0.9707
May	34.1488	17.2075	0.0501
Jun	27.3539	16.4164	0.0989
Jul	25.3417	16.7920	0.1345
Aug	29.7407	16.4227	0.0733
Sep	30.4804	16.6688	0.0706
Oct	30.1635	16.4031	0.0690
Nov	6.4546	4.3083	0.1374
Dec	10.1343	3.7802	0.0086
Trend	0.0365	0.0422	0.3896
INV(1)	0.4012	0.0940	0.0001*
R-squared: 0.6728 Durbin-Watson = 1.9511		F-Stat(19,115)=10.9668 Prob. of F-stat= 0.0001*	

Table A.14. Cow inventory 18 month cumulative profit (Robinson), Jan. 2000 to Dec. 2009

Variables	Coefficient	Standard Error	P-Value
Intercept	-44.4466	11.3573	0.0002
CULLD	-0.0001	0.0001	0.0411
CULLD(1)	-0.0002	0.0001	0.0029
CULLD(2)	-0.0002	0.0001	0.0034
REPD(3)	0.0002	0.0001	0.0971
PRF18 Robinson	0.0177	0.0042	0.0001
Feb	1.9432	4.2025	0.6448
Mar	6.5107	4.7211	0.1711
Apr	0.2427	5.3448	0.9639
May	37.4631	19.5053	0.0577
Jun	30.4289	18.6462	0.1060
Jul	28.2189	19.1370	0.1436
Aug	32.3158	18.7376	0.0878
Sep	33.1817	18.9872	0.0837
Oct	32.9173	18.6653	0.0810
Nov	6.0465	4.4916	0.1814
Dec	9.8143	3.7904	0.0111
Trend	-0.1953	0.0707	0.0069
INV(1)	0.5430	0.0862	0.0001*
R-squared: 0.6383 Durbin-Watson = 2.0423		F-Stat(19,115)=9.4100 Prob. of F-stat= 0.0001*	

Table A.15. Cow inventory 21 month cumulative profit (ARFJA), Jan. 2000 to Dec. 2009

Variables	Coefficient	Standard Error	P-Value
Intercept	-30.5609	9.3530	0.0015
CULLD	-0.0001	0.0001	0.0276
CULLD(1)	-0.0002	0.0001	0.0011
CULLD(2)	-0.0002	0.0001	0.0014
REPD(3)	0.0002	0.0001	0.0956
PRF21 ARFJA	0.0149	0.0026	0.0001*
Feb	1.7604	4.2415	0.6790
Mar	6.0236	4.6306	0.1964
Apr	-0.3997	5.1546	0.9384
May	35.3164	18.0962	0.0539
Jun	28.4131	17.2762	0.1033
Jul	26.8180	17.6727	0.1324
Aug	31.5882	17.2745	0.0706
Sep	32.6226	17.5163	0.0656
Oct	32.2733	17.2332	0.0641
Nov	6.7961	4.4007	0.1258
Dec	10.2499	3.8092	0.0084
Trend	0.0254	0.0466	0.5863
INV(1)	0.4477	0.0917	0.0001*
R-squared: 0.6576 Durbin-Watson = 1.9662		F-Stat(19,115)=10.2451 Prob. of F-stat= 0.0001*	

Table A.16. Cow inventory 21 month cumulative profit (Robinson), Jan. 2000 to Dec. 2009

Variables	Coefficient	Standard Error	P-Value
Intercept	-44.7245	12.9424	0.0008
CULLD	-0.0001	0.0001	0.0385
CULLD(1)	-0.0002	0.0001	0.0027
CULLD(2)	-0.0002	0.0001	0.0032
REPD(3)	0.0002	0.0001	0.1231
PRF21 Robinson	0.0157	0.0049	0.0018
Feb	1.9602	4.2128	0.6428
Mar	6.3636	4.8021	0.1883
Apr	0.1895	5.4857	0.9725
May	36.8218	20.3731	0.0738
Jun	29.8068	19.4967	0.1296
Jul	27.7101	20.0223	0.1696
Aug	32.0659	19.5984	0.1051
Sep	33.0359	19.8428	0.0992
Oct	32.7020	19.5009	0.0968
Nov	6.2556	4.5761	0.1748
Dec	9.8153	3.8108	0.0115
Trend	-0.2083	0.0875	0.0193
INV(1)	0.5934	0.0827	0.0001*
R-squared: 0.6224 Durbin-Watson = 2.0669		F-Stat(19,115)=8.7921 Prob. of F-stat= 0.0001*	

Table A.17. Cow inventory 24 month cumulative profit (ARFJA), Jan. 2000 to Dec. 2009

Variables	Coefficient	Standard Error	P-Value
Intercept	-30.6753	9.8683	0.0025
CULLD	-0.0001	0.0001	0.0323
CULLD(1)	-0.0002	0.0001	0.0016
CULLD(2)	-0.0002	0.0001	0.0020
REPD(3)	0.0002	0.0001	0.1168
PRF24 ARFJA	0.0142	0.0029	0.0001*
Feb	1.4872	4.2314	0.7260
Mar	5.5844	4.6888	0.2366
Apr	-0.7980	5.2627	0.8798
May	34.2691	18.9354	0.0735
Jun	27.3242	18.0948	0.1343
Jul	25.5045	18.5288	0.1719
Aug	30.3460	18.1068	0.0970
Sep	31.5016	18.3449	0.0892
Oct	31.3642	18.0347	0.0852
Nov	6.6834	4.4564	0.1370
Dec	10.3407	3.8124	0.0079
Trend	0.0162	0.0514	0.7528
INV(1)	0.4932	0.0894	0.0001*
R-squared: 0.6471 Durbin-Watson = 1.9941		F-Stat(19,115)=9.7791 Prob. of F-stat= 0.0001*	

Table A.18. Cow inventory 24 month cumulative profit (Robinson), Jan. 2000 to Dec. 2009

Variables	Coefficient	Standard Error	P-Value
Intercept	-44.6926	14.7643	0.0032
CULLD	-0.0001	0.0001	0.0423
CULLD(1)	-0.0002	0.0001	0.0034
CULLD(2)	-0.0002	0.0001	0.0040
REPD(3)	0.0002	0.0001	0.1775
PRF24 Robinson	0.0146	0.0057	0.0122
Feb	1.6477	4.1906	0.6951
Mar	5.9434	4.8390	0.2224
Apr	-0.1163	5.5672	0.9834
May	33.4806	21.0713	0.1154
Jun	26.6510	20.1894	0.1900
Jul	24.3136	20.7504	0.2442
Aug	28.8016	20.3022	0.1592
Sep	29.7229	20.5390	0.1511
Oct	29.5092	20.1717	0.1468
Nov	6.2286	4.6114	0.1800
Dec	9.8951	3.8025	0.0107
Trend	-0.2233	0.1074	0.0403
INV(1)	0.6364	0.0795	0.0001*
R-squared: 0.6139 Durbin-Watson = 2.1028		F-Stat(19,115)=8.4804 Prob. of F-stat= 0.0001*	

Table A.19. Milk yield per cow with feed cost (ARFJA), Jan. 2000 to Dec. 2009

Variables	Coefficient	Standard Error	P-Value
Intercept	1517.2610	10.2858	0.0001*
FC (Feed Cost) ARFJA	-0.0845	0.0695	0.2267
CULLD	0.0001	0.0000	0.2645
FEB	-119.5998	4.6960	0.0001*
MAR	47.2278	4.8910	0.0001*
APR	13.5794	5.7908	0.0210
MAY	69.0553	5.9376	0.0001*
JUN	-14.8013	5.9733	0.0149
JUL	-15.7453	5.9760	0.0097
AUG	-40.2498	5.8472	0.0001*
SEP	-105.9641	5.8246	0.0001*
OCT	-60.1001	5.4283	0.0001*
NOV	-104.5286	5.1687	0.0001*
DEC	-32.6636	3.9700	0.0001*
T	2.2886	0.1256	0.0001*
PPC(1)	0.6374	0.0614	0.0001*
R-squared: 0.9881 Durbin-Watson = 2.2528		F-Stat(16,118)=565.7703 Prob. of F-stat = 0.0001*	

Table A.20. Milk yield per cow with feed cost (Robinson), Jan. 2000 to Dec. 2009

Variables	Coefficient	Standard Error	P-Value
Intercept	1512.7510	13.6473	0.0001*
FC (Feed Cost) Robinson	-0.0743	0.1737	0.6699
CULLD	0.0001*	0.0001*	0.2815
FEB	-118.9990	4.8477	0.0001*
MAR	46.9152	4.9168	0.0001*
APR	13.3392	5.8295	0.0242
MAY	68.4621	6.2037	0.0001*
JUN	-15.1941	6.0890	0.0142
JUL	-15.9952	6.1323	0.0105
AUG	-40.0854	5.9518	0.0001*
SEP	-105.4453	5.8583	0.0001*
OCT	-59.4971	5.4515	0.0001*
NOV	-103.8316	5.1711	0.0001*
DEC	-32.4332	3.9768	0.0001*
T	2.2177	0.1277	0.0001*
PPC(1)	0.6477	0.0612	0.0001*
R-squared: 0.9879 Durbin-Watson = 2.2412		F-Stat(16,118)=558.8869 Prob. of F-stat = 0.0001*	

Table A.21. Milk yield per cow with profit (ARFJA), Jan. 2000 to Dec. 2009

Variables	Coefficient	Standard Error	P-Value
Intercept	1506.4150	7.4113	0.0001*
Profit ARFJA	0.0330	0.0413	0.4260
CULLD	0.0001	0.0001*	0.2502
FEB	-117.9574	4.6085	0.0001*
MAR	46.8507	4.8997	0.0001*
APR	13.1819	5.8152	0.0255
MAY	67.4993	5.8837	0.0001*
JUN	-15.7983	5.9907	0.0097
JUL	-16.6577	5.9963	0.0065
AUG	-40.6521	5.8981	0.0001*
SEP	-105.8044	5.8603	0.0001*
OCT	-60.1081	5.4808	0.0001*
NOV	-103.6690	5.1226	0.0001*
DEC	-32.7438	3.9964	0.0001*
T	2.1896	0.0856	0.0001*
PPC(1)	0.6456	0.0616	0.0001*
R-squared: 0.9880 Durbin-Watson = 2.2491		F-Stat(16,118)=561.3937 Prob. of F-stat = 0.0001*	

Table A.22. Milk yield per cow with profit (Robinson), Jan. 2000 to Dec. 2009

Variables	Coefficient	Standard Error	P-Value
Intercept	1506.4150	7.4113	0.0001*
Profit Robinson	0.0330	0.0413	0.4260
CULLD	0.0001	0.0001*	0.2502
FEB	-117.9574	4.6085	0.0001*
MAR	46.8507	4.8997	0.0001*
APR	13.1819	5.8152	0.0255
MAY	67.4993	5.8837	0.0001*
JUN	-15.7983	5.9907	0.0097
JUL	-16.6577	5.9963	0.0065
AUG	-40.6521	5.8981	0.0001*
SEP	-105.8044	5.8603	0.0001*
OCT	-60.1081	5.4808	0.0001*
NOV	-103.6690	5.1226	0.0001*
DEC	-32.7438	3.9964	0.0001*
T	2.1896	0.0856	0.0001*
PPC(1)	0.6456	0.0616	0.0001*
R-squared: 0.9880 Durbin-Watson = 2.2491		F-Stat(16,118)=561.3937 Prob. of F-stat = 0.0001*	

Table A.23. Milk yield per cow 3 month cumulative profit (ARFJA), Jan. 2000 to Dec. 2009

Variables	Coefficient	Standard Error	P-Value
Intercept	1504.5360	7.4134	0.0001*
PRF3 ARFJA	0.0246	0.0165	0.1394
CULLD	0.0001*	0.0001*	0.3077
FEB	-118.1738	4.5666	0.0001*
MAR	47.5475	4.8811	0.0001*
APR	13.7241	5.7680	0.0192
MAY	67.7720	5.8219	0.0001*
JUN	-15.7224	5.9240	0.0092
JUL	-16.5934	5.9283	0.0061
AUG	-40.4630	5.8253	0.0001*
SEP	-105.7372	5.7892	0.0001*
OCT	-60.0545	5.4000	0.0001*
NOV	-104.1224	5.1013	0.0001*
DEC	-32.8875	3.9647	0.0001*
T	2.2046	0.0842	0.0001*
PPC(1)	0.6369	0.0621	0.0001*
R-squared: 0.9882 Durbin-Watson = 2.2569		F-Stat(16,118)=570.0163 Prob. of F-stat = 0.0001*	

Table A.24. Milk yield per cow 3 month cumulative profit (Robinson), Jan. 2000 to Dec. 2009

Variables	Coefficient	Standard Error	P-Value
Intercept	1503.9200	8.7778	0.0001*
PRF3 Robinson	0.0148	0.0187	0.4308
CULLD	0.0001*	0.0001*	0.2947
FEB	-118.2489	4.5773	0.0001*
MAR	47.0538	4.9064	0.0001*
APR	13.3175	5.8137	0.0240
MAY	67.3484	5.8982	0.0001*
JUN	-16.0339	6.0179	0.0090
JUL	-16.8965	6.0236	0.0060
AUG	-40.6558	5.9075	0.0001*
SEP	-105.6823	5.8568	0.0001*
OCT	-59.7835	5.4472	0.0001*
NOV	-103.7278	5.1233	0.0001*
DEC	-32.5663	3.9704	0.0001*
T	2.1606	0.0868	0.0001*
PPC(1)	0.6500	0.0615	0.0001*
R-squared: 0.9880 Durbin-Watson = 2.2473		F-Stat(16,118)=561.4105 Prob. of F-stat = 0.0001*	

Table A.25. Milk yield per cow 6 month cumulative profit (ARFJA), Jan. 2000 to Dec. 2009

Variables	Coefficient	Standard Error	P-Value
Intercept	1502.2830	7.4087	0.0001*
PRF6 ARFJA	0.0193	0.0092	0.0373
CULLD	0.0001*	0.0001*	0.2638
FEB	-117.9985	4.5359	0.0001*
MAR	47.6519	4.8249	0.0001*
APR	14.4604	5.7164	0.0129
MAY	68.7798	5.7607	0.0001*
JUN	-14.4653	5.8566	0.0152
JUL	-15.5613	5.8553	0.0091
AUG	-39.8198	5.7480	0.0001*
SEP	-105.1605	5.7117	0.0001*
OCT	-59.5116	5.3249	0.0001*
NOV	-103.4797	5.0370	0.0001*
DEC	-32.4250	3.9180	0.0001*
T	2.2165	0.0820	0.0001*
PPC(1)	0.6282	0.0630	0.0001*
R-squared: 0.9885 Durbin-Watson = 2.2663		F-Stat(16,118)=582.2348 Prob. of F-stat = 0.0001*	

Table A.26. Milk yield per cow 6 month cumulative profit (Robinson), Jan. 2000 to Dec. 2009

Variables	Coefficient	Standard Error	P-Value
Intercept	1500.8490	9.3120	0.0001*
PRF6 Robinson	0.0130	0.0109	0.2339
CULLD	0.0001*	0.0001*	0.2704
FEB	-118.0525	4.5666	0.0001*
MAR	47.1556	4.8847	0.0001*
APR	13.6817	5.7975	0.0202
MAY	67.8564	5.8614	0.0001*
JUN	-15.4387	5.9690	0.0111
JUL	-16.4400	5.9763	0.0070
AUG	-40.5822	5.8746	0.0001*
SEP	-105.6758	5.8278	0.0001*
OCT	-59.8178	5.4220	0.0001*
NOV	-103.6218	5.0997	0.0001*
DEC	-32.4389	3.9488	0.0001*
T	2.1465	0.0873	0.0001*
PPC(1)	0.6486	0.0619	0.0001*
R-squared: 0.9881 Durbin-Watson = 2.2550		F-Stat(16,118)=565.9270 Prob. of F-stat = 0.0001*	

Table A.27. Milk yield per cow 12 month cumulative profit (ARFJA), Jan. 2000 - Dec. 2009

Variables	Coefficient	Standard Error	P-Value
Intercept	1501.6600	6.9123	0.0001*
PRF12 ARFJA	0.0131	0.0050	0.0093
CULLD	0.0001*	0.0001*	0.2814
FEB	-118.5822	4.5440	0.0001*
MAR	46.8849	4.7867	0.0001*
APR	13.4192	5.6455	0.0193
MAY	67.8411	5.6575	0.0001*
JUN	-15.3853	5.7323	0.0085
JUL	-16.2115	5.7285	0.0056
AUG	-40.0144	5.6324	0.0001*
SEP	-105.0093	5.6188	0.0001*
OCT	-59.0816	5.2571	0.0001*
NOV	-103.0988	5.0082	0.0001*
DEC	-31.9317	3.9217	0.0001*
T	2.2111	0.0746	0.0001*
PPC(1)	0.6002	0.0646	0.0001*
R-squared: 0.9887 Durbin-Watson = 2.2366		F-Stat(16,118)=592.3557 Prob. of F-stat = 0.0001*	

Table A.28. Milk yield per cow 12 month cumulative profit (Robinson), Jan. 2000 - Dec. 2009

Variables	Coefficient	Standard Error	P-Value
Intercept	1500.6080	9.6716	0.0001*
PRF12 Robinson	0.0072	0.0065	0.2710
CULLD	0.0001*	0.0001*	0.2796
FEB	-118.4165	4.5805	0.0001*
MAR	46.7024	4.8884	0.0001*
APR	13.1521	5.7966	0.0254
MAY	67.5415	5.8574	0.0001*
JUN	-15.6890	5.9601	0.0098
JUL	-16.5164	5.9661	0.0067
AUG	-40.3318	5.8628	0.0001*
SEP	-105.3165	5.8211	0.0001*
OCT	-59.3884	5.4202	0.0001*
NOV	-103.3736	5.1121	0.0001*
DEC	-32.1805	3.9662	0.0001*
T	2.1360	0.0897	0.0001*
PPC(1)	0.6409	0.0624	0.0001*
R-squared: 0.9881 Durbin-Watson = 2.2333		F-Stat(16,118)=564.4576 Prob. of F-stat = 0.0001*	

Table A.29. Milk yield per cow 15 month cumulative profit (ARFJA), Jan. 2000 - Dec. 2009

Variables	Coefficient	Standard Error	P-Value
Intercept	1500.9620	6.7561	0.0001*
PRF15 ARFJA	0.0128	0.0043	0.0035
CULLD	0.0001*	0.0001*	0.2913
FEB	-118.5546	4.5274	0.0001*
MAR	47.1008	4.7529	0.0001*
APR	13.5334	5.5991	0.0174
MAY	67.7251	5.6023	0.0001*
JUN	-15.6716	5.6720	0.0068
JUL	-16.5530	5.6656	0.0043
AUG	-40.3659	5.5701	0.0001*
SEP	-105.4275	5.5618	0.0001*
OCT	-59.5185	5.2086	0.0001*
NOV	-103.4018	4.9734	0.0001*
DEC	-32.0683	3.9031	0.0001*
T	2.2068	0.0718	0.0001*
PPC(1)	0.5910	0.0656	0.0001*
R-squared: 0.9888 Durbin-Watson = 2.2386		F-Stat(16,118)=601.0622 Prob. of F-stat = 0.0001*	

Table A.30. Milk yield per cow 15 month cumulative profit (Robinson), Jan. 2000 - Dec. 2009

Variables	Coefficient	Standard Error	P-Value
Intercept	1497.9490	10.0292	0.0001*
PRF15 Robinson	0.0082	0.0059	0.1666
CULLD	0.0001*	0.0001*	0.2829
FEB	-118.4222	4.5712	0.0001*
MAR	46.7160	4.8720	0.0001*
APR	13.0882	5.7762	0.0256
MAY	67.2663	5.8393	0.0001*
JUN	-16.0432	5.9416	0.0081
JUL	-16.8859	5.9455	0.0054
AUG	-40.6464	5.8389	0.0001*
SEP	-105.5930	5.7967	0.0001*
OCT	-59.6115	5.3978	0.0001*
NOV	-103.4561	5.0948	0.0001*
DEC	-32.1919	3.9560	0.0001*
T	2.1117	0.0931	0.0001*
PPC(1)	0.6375	0.0633	0.0001*
R-squared: 0.9882 Durbin-Watson = 2.2362		F-Stat(16,118)=568.2679 Prob. of F-stat = 0.0001*	

Table A.31. Milk yield per cow 18 month cumulative profit (ARFJA), Jan. 2000 - Dec. 2009

Variables	Coefficient	Standard Error	P-Value
Intercept	1500.6420	6.7641	0.0001*
PRF18 ARFJA	0.0111	0.0039	0.0052
CULLD	0.0001*	0.0001*	0.2965
FEB	-118.4259	4.5674	0.0001*
MAR	47.3284	4.7788	0.0001*
APR	13.8922	5.6217	0.0151
MAY	68.2281	5.6128	0.0001*
JUN	-15.0502	5.6774	0.0093
JUL	-15.9773	5.6700	0.0058
AUG	-39.9999	5.5755	0.0001*
SEP	-105.2027	5.5736	0.0001*
OCT	-59.3307	5.2259	0.0001*
NOV	-103.2475	5.0032	0.0001*
DEC	-31.9540	3.9368	0.0001*
T	2.1989	0.0700	0.0001*
PPC(1)	0.5812	0.0670	0.0001*
R-squared: 0.9887 Durbin-Watson = 2.2050		F-Stat(16,118)=594.9377 Prob. of F-stat = 0.0001*	

Table A.32. Milk yield per cow 18 month cumulative profit (Robinson), Jan. 2000 - Dec. 2009

Variables	Coefficient	Standard Error	P-Value
Intercept	1498.1930	10.7794	0.0001*
PRF18 Robinson	0.0068	0.0057	0.2419
CULLD	0.0001*	0.0001*	0.2825
FEB	-118.2886	4.5915	0.0001*
MAR	46.8512	4.8855	0.0001*
APR	13.2704	5.7875	0.0239
MAY	67.5281	5.8410	0.0001*
JUN	-15.7470	5.9399	0.0093
JUL	-16.6299	5.9447	0.0062
AUG	-40.5870	5.8438	0.0001*
SEP	-105.6101	5.8060	0.0001*
OCT	-59.6658	5.4094	0.0001*
NOV	-103.4973	5.1105	0.0001*
DEC	-32.2157	3.9724	0.0001*
T	2.1088	0.0986	0.0001*
PPC(1)	0.6331	0.0644	0.0001*
R-squared: 0.9881 Durbin-Watson = 2.2201		F-Stat(16,118)=565.0913 Prob. of F-stat = 0.0001*	

Table A.33. Milk yield per cow 21 month cumulative profit (ARFJA), Jan. 2000 - Dec. 2009

Variables	Coefficient	Standard Error	P-Value
Intercept	1499.6390	6.7505	0.0001*
PRF21 ARFJA	0.0110	0.0037	0.0035
CULLD	0.0001*	0.0001*	0.2964
FEB	-118.5241	4.5844	0.0001*
MAR	47.1468	4.7767	0.0001*
APR	13.6746	5.6103	0.0165
MAY	68.1265	5.5866	0.0001*
JUN	-15.0354	5.6437	0.0090
JUL	-15.8057	5.6345	0.0060
AUG	-39.6723	5.5426	0.0001*
SEP	-104.7244	5.5504	0.0001*
OCT	-58.8670	5.2121	0.0001*
NOV	-102.9496	5.0051	0.0001*
DEC	-31.7761	3.9504	0.0001*
T	2.1934	0.0677	0.0001*
PPC(1)	0.5689	0.0681	0.0001*
R-squared: 0.9887 Durbin-Watson = 2.1774		F-Stat(16,118)=596.2871 Prob. of F-stat = 0.0001*	

Table A.34. Milk yield per cow 21 month cumulative profit (Robinson), Jan. 2000 - Dec. 2009

Variables	Coefficient	Standard Error	P-Value
Intercept	1496.6810	11.9061	0.0001*
PRF21 Robinson	0.0067	0.0058	0.2496
CULLD	0.0001*	0.0001*	0.2823
FEB	-118.2685	4.6035	0.0001*
MAR	46.8476	4.8894	0.0001*
APR	13.2748	5.7881	0.0239
MAY	67.6093	5.8342	0.0001*
JUN	-15.6462	5.9295	0.0096
JUL	-16.4889	5.9330	0.0065
AUG	-40.3794	5.8313	0.0001*
SEP	-105.3522	5.7987	0.0001*
OCT	-59.4285	5.4074	0.0001*
NOV	-103.4127	5.1165	0.0001*
DEC	-32.1892	3.9818	0.0001*
T	2.0962	0.1046	0.0001*
PPC(1)	0.6277	0.0654	0.0001*
R-squared: 0.9881 Durbin-Watson = 2.2038		F-Stat(16,118)=564.5640 Prob. of F-stat = 0.0001*	

Table A.35. Milk yield per cow 24 month cumulative profit (ARFJA), Jan. 2000 - Dec. 2009

Variables	Coefficient	Standard Error	P-Value
Intercept	1497.8020	6.5794	0.0001*
PRF24 ARFJA	0.0125	0.0035	0.0006
CULLD	0.0001*	0.0001*	0.3006
FEB	-118.8171	4.5690	0.0001*
MAR	46.8644	4.7305	0.0001*
APR	13.3187	5.5411	0.0180
MAY	67.6586	5.4950	0.0001*
JUN	-15.6418	5.5386	0.0057
JUL	-16.4467	5.5224	0.0036
AUG	-40.1412	5.4318	0.0001*
SEP	-105.0346	5.4519	0.0001*
OCT	-58.9667	5.1322	0.0001*
NOV	-102.8660	4.9555	0.0001*
DEC	-31.5105	3.9333	0.0001*
T	2.1876	0.0638	0.0001*
PPC(1)	0.5494	0.0693	0.0001*
R-squared: 0.9890 Durbin-Watson = 2.1752		F-Stat(16,118)=610.0791 Prob. of F-stat = 0.0001*	

Table A.36. Milk yield per cow 24 month cumulative profit (Robinson), Jan. 2000 - Dec. 2009

Variables	Coefficient	Standard Error	P-Value
Intercept	1489.5220	12.9321	0.0001*
PRF24 Robinson	0.0097	0.0058	0.0973
CULLD	0.0001*	0.0001*	0.2854
FEB	-118.4706	4.6029	0.0001*
MAR	46.6121	4.8675	0.0001*
APR	12.9723	5.7522	0.0263
MAY	67.2669	5.7825	0.0001*
JUN	-16.0385	5.8687	0.0074
JUL	-16.8619	5.8664	0.0049
AUG	-40.6229	5.7642	0.0001*
SEP	-105.5210	5.7394	0.0001*
OCT	-59.5026	5.3610	0.0001*
NOV	-103.3761	5.0920	0.0001*
DEC	-32.0584	3.9782	0.0001*
T	2.0420	0.1090	0.0001*
PPC(1)	0.6128	0.0671	0.0001*
R-squared: 0.9882 Durbin-Watson = 2.1907		F-Stat(16,118)=571.3940 Prob. of F-stat = 0.0001*	

APPENDIX B

Results of the autoregressive model's forecast

Table B.1. Ex-post forecast of Class III milk prices ($/cwt.) from autoregressive model

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
January	10.0500	10.6438	11.2373	11.8380	12.2507	12.5997	13.0640	13.5450	14.0704	14.3875	**14.6609**	**15.1914**	**15.6259**
February	9.6866	10.2919	10.8984	11.4426	11.8639	12.1267	12.6713	13.1216	13.6659	13.9515	**14.3225**	**14.8413**	**15.2267**
March	10.0478	10.6282	11.2519	11.7748	12.1545	12.5303	13.0186	13.5175	14.1174	14.2951	**14.6450**	**15.1990**	**15.5409**
April	10.7736	11.3690	11.9019	12.4475	12.8035	13.2633	13.6298	14.1856	14.8068	14.9522	**15.2729**	**15.8347**	**16.1941**
May	11.1785	11.7847	12.3168	12.8095	13.2378	13.6467	14.0410	14.6161	15.1505	15.3241	**15.6694**	**16.2151**	**16.6244**
June	11.5427	12.1249	12.6627	13.0701	13.6318	13.9049	14.2535	14.8944	15.4469	15.5373	**15.9168**	**16.5026**	**16.9352**
July	11.5073	12.0108	12.5648	13.0067	13.4976	13.8415	14.2229	14.8623	15.3112	15.5154	**15.8875**	**16.3856**	**16.9215**
August	11.4261	12.0204	12.4598	12.9274	13.4213	13.7349	14.1592	14.8052	15.2758	15.4290	**15.7616**	**16.2877**	
September	11.8211	12.4090	12.9099	13.3915	13.8864	14.2618	14.6257	15.2745	15.7306	15.8732	**16.2848**	**16.7789**	
October	11.7051	12.2696	12.7868	13.2637	13.6772	14.0948	14.5005	15.1255	15.5656	15.7117	**16.1939**	**16.6160**	
November	11.1376	11.6683	12.2412	12.6663	13.0326	13.4812	13.8916	14.5475	14.9414	15.1077	**15.5692**	**16.0528**	
December	11.4369	11.9816	12.6246	13.0253	13.3985	13.8222	14.2874	14.8446	15.2161	15.5141	**16.0091**	**16.3856**	

Table B.2. Out-of sample forecast of Class III milk prices ($/cwt.) from autoregressive model

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Jan	10.0500	10.8468	11.3827	11.6073	12.1125	12.6575	13.1728	13.5781	13.9652	14.5262	14.9720	15.2924	15.7136	**16.1670**	**16.3454**
Feb	9.6340	10.3747	10.9021	11.1517	11.7333	12.2954	12.7260	13.0970	13.5222	14.1232	14.5489	14.8914	15.2757	**15.7835**	**15.9977**
Mar	10.0231	10.7127	11.3065	11.4980	12.1293	12.5860	13.0514	13.4709	13.8917	14.5306	14.8035	15.1643	15.6381	**16.1782**	**16.3844**
Apr	10.7313	11.4144	11.9303	12.0923	12.7746	13.2205	13.6909	14.1807	14.5461	15.2249	15.4288	15.8417	16.2889	**16.7704**	**17.0378**
May	11.2043	11.8516	12.2950	12.4933	13.1430	13.7036	14.0972	14.6008	14.9676	15.6066	15.7420	16.2337	16.6992	**17.1135**	**17.4485**
Jun	11.5586	12.2496	12.5254	12.7608	13.4548	14.0467	14.4305	14.9092	15.2559	15.8277	16.0633	16.5059	17.0317	**17.3831**	**17.7331**
Jul	11.5591	12.2425	12.4001	12.7198	13.3569	13.9208	14.3758	14.7999	15.1777	15.7492	15.9736	16.4301	16.9445	**17.2683**	**17.8003**
Aug	11.5772	12.1359	12.3266	12.7695	13.2922	13.8722	14.2174	14.6708	15.1574	15.6319	15.9286	16.3581	**16.8475**	**17.1201**	
Sep	12.0902	12.6383	12.7833	13.2578	13.7585	14.4066	14.6868	15.1132	15.6025	16.1075	16.3969	16.8502	**17.3075**	**17.5944**	
Oct	11.8701	12.4884	12.6144	13.1232	13.5821	14.2252	14.5634	14.9583	15.4599	15.9348	16.2786	16.6885	**17.1461**	**17.4498**	
Nov	11.2373	11.9598	12.0821	12.5056	13.0161	13.6740	13.9898	14.3271	14.8791	15.4455	15.6456	16.1127	**16.5142**	**16.7978**	
Dec	11.6283	12.2043	12.4766	12.8741	13.4015	14.0213	14.3634	14.7172	15.3286	15.7797	16.0618	16.5071	**16.9095**	**17.2070**	

APPENDIX C

Results of the log of consumption model and the forecasts of the log of consumption model

Table C.1. Ex-post forecast of Class III milk prices ($/cwt.) from the log of consumption model, Jan. 2000 to July 2012

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
January	11.8677	11.3098	10.9084	11.2070	10.6982	13.4810	11.6691	12.7427	15.6541	12.8744	**13.7172**	**18.7749**	**18.0692**
February	11.4264	10.3527	10.3117	10.5455	10.4992	13.4335	12.1787	13.0834	15.8101	11.4488	**13.4728**	**16.6967**	**16.8758**
March	11.5260	10.3501	9.9998	10.3481	11.7788	13.8417	12.7004	13.3288	16.9103	12.2183	**15.2190**	**19.2285**	**19.1786**
April	11.7464	11.0193	11.3205	10.5209	12.3027	12.7939	13.4839	14.2936	17.6520	12.5045	**17.1475**	**17.4209**	**20.3949**
May	11.2168	11.1104	10.6254	10.3721	11.4212	13.7626	15.2242	15.8113	19.2847	13.1149	**21.6420**	**18.3263**	**23.5740**
June	11.3422	11.3369	11.2275	11.3669	12.5363	12.7640	15.0360	15.0009	19.5020	13.6955	**20.7402**	**18.8535**	**21.1340**
July	12.0089	11.2335	10.9580	11.7316	12.6782	12.6564	15.1728	15.3796	18.3177	13.6967	**17.6253**	**18.5071**	**18.7732**
August	11.1772	11.7575	11.1948	11.1940	14.1528	13.3190	14.4625	14.2307	18.5282	13.6188	**19.2587**	**18.8033**	
September	12.2663	12.3041	11.8562	11.6044	14.4596	13.3941	15.0871	17.1211	16.7722	14.3465	**21.2635**	**19.1895**	
October	12.1599	13.7601	11.2050	11.3265	13.6706	12.6117	14.8515	16.6472	15.4731	16.4562	**20.8108**	**17.8464**	
November	11.4279	11.7849	12.1824	11.5326	13.5423	12.4355	12.4818	17.3930	13.0820	15.3390	**17.4692**	**19.4490**	
December	11.4504	12.3147	11.9865	11.5809	15.8075	13.0194	13.2289	16.1214	13.6579	14.7257	**19.3328**	**19.3735**	

Table C.2. Out-of-sample forecast of Class III milk prices ($/cwt.) from the log of consumption model, Jan. 2000 to July 2014.

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Jan	10.0500	11.3854	10.9188	11.1706	10.7538	13.4974	11.5629	12.8919	15.6592	12.8771	13.5846	18.7430	18.2684	**18.9786**	**19.3413**
Feb	9.5400	10.3023	10.4847	10.6132	10.3627	13.5864	12.1159	12.9011	15.8505	11.6231	13.3515	16.8880	16.6793	**18.3019**	**19.5090**
Mar	11.4555	10.2830	10.0523	10.1143	11.6587	13.8233	12.7002	13.2597	16.9944	12.2533	15.3488	19.0272	19.0679	**22.1000**	**25.8675**
Apr	11.6055	11.0634	11.4825	10.4031	12.3264	12.8623	13.4787	14.3680	17.7873	12.5609	17.0260	17.5257	20.4211	**21.9958**	**23.3489**
May	11.1634	11.1580	10.5863	10.4039	11.3807	13.9355	15.2445	15.8519	19.6091	13.0745	21.2842	18.5124	23.5068	**26.1187**	**29.9355**
Jun	11.2892	11.3480	11.0853	11.4751	12.4865	12.8019	14.9962	15.0142	19.2266	13.7859	20.8993	19.1279	21.1125	**22.3423**	**23.5804**
Jul	12.0449	11.1839	10.9352	11.8432	12.6071	12.7122	15.1897	15.1930	18.0337	13.7262	17.6390	18.4067	18.8070	**19.8922**	**20.9517**
Aug	11.2809	11.7776	11.3374	11.2588	14.2639	13.3742	14.5705	14.3900	18.5412	13.7161	19.3006	18.7368	**20.9660**	**24.0783**	
Sep	12.1403	12.3432	11.7940	11.8493	14.4313	13.3715	15.1531	17.1258	16.6462	14.3736	21.2911	19.0126	**19.2986**	**19.8579**	
Oct	12.2436	13.6488	11.2929	11.0944	13.8290	12.6993	14.8344	16.6729	15.4359	16.1814	20.7795	17.8486	**19.4877**	**21.7051**	
Nov	11.3256	11.8281	12.1050	11.5724	13.3548	12.3841	12.6077	17.3837	13.1713	15.2776	17.2644	19.3504	**20.3789**	**21.2965**	
Dec	11.6116	12.3936	11.9650	11.5348	15.6008	13.2131	13.2976	15.9880	13.7774	14.6835	19.4356	19.6110	**20.6949**	**22.2858**	

APPENDIX D

Regressions for the VAR models, cointegration results, and the forecasts of the two models

Table D.1. **Unrestricted vector autoregressive model, January 2000 to December 2009**

Sample (adjusted): 2000M08 2010M07 Included observations: 120 after adjustments
Standard errors in ( ) & t-statistics in [ ]

	CLASS3	STORD	PRODF_N	EXPD	CHPRODD	PRF12
CLASS3(-1)	1.223640	-1587.240	3.107191	-3335597.	-1904.178	1.965881
	(0.09862)	(1240.14)	(0.87896)	(1407242)	(1061.15)	(2.59999)
	[12.4081]	[-1.27989]	[3.53508]	[-2.37031]	[-1.79444]	[0.75611]
CLASS3(-2)	-0.250274	1316.619	-0.021035	2717300.	444.0041	-1.870915
	(0.10439)	(1312.69)	(0.93038)	(1489569)	(1123.23)	(2.75210)
	[-2.39760]	[1.00299]	[-0.02261]	[1.82422]	[0.39529]	[-0.67981]
STORD(-1)	-1.27E-05	0.242914	-2.58E-05	-122.0728	-0.034866	-0.000702
	(8.0E-06)	(0.10022)	(7.1E-05)	(113.727)	(0.08576)	(0.00021)
	[-1.59594]	[2.42373]	[-0.36291]	[-1.07338]	[-0.40656]	[-3.34191]
STORD(-2)	1.05E-06	-0.145217	3.21E-05	207.0483	-0.121157	-5.67E-05
	(8.1E-06)	(0.10197)	(7.2E-05)	(115.715)	(0.08726)	(0.00021)
	[0.12972]	[-1.42405]	[0.44436]	[1.78930]	[-1.38851]	[-0.26535]
PRODF_N(-1)	-0.019082	5.284619	0.266735	77349.56	41.00238	-0.071896
	(0.01098)	(138.096)	(0.09788)	(156703.)	(118.165)	(0.28952)
	[-1.73764]	[0.03827]	[2.72523]	[0.49360]	[0.34699]	[-0.24833]
PRODF_N(-2)	0.007546	-97.02706	0.296915	-77385.76	-64.50294	-0.101075
	(0.00798)	(100.346)	(0.07112)	(113867.)	(85.8633)	(0.21038)
	[0.94562]	[-0.96692]	[4.17479]	[-0.67961]	[-0.75123]	[-0.48044]
EXPD(-1)	6.76E-09	-7.89E-05	4.13E-08	-0.214214	7.17E-05	1.99E-07
	(7.3E-09)	(9.2E-05)	(6.5E-08)	(0.10453)	(7.9E-05)	(1.9E-07)
	[0.92261]	[-0.85615]	[0.63266]	[-2.04929]	[0.90955]	[1.02994]
EXPD(-2)	1.91E-08	-9.41E-05	-3.89E-08	-0.006475	-0.000134	3.76E-07
	(7.5E-09)	(9.4E-05)	(6.6E-08)	(0.10646)	(8.0E-05)	(2.0E-07)

	[2.56661]	[-1.00248]	[-0.58490]	[-0.06082]	[-1.66979]	[1.90965]
CHPRODD(-1)	1.74E-05	0.014150	-0.000178	-183.4608	-0.425722	3.74E-05
	(9.4E-06)	(0.11775)	(8.3E-05)	(133.618)	(0.10076)	(0.00025)
	[1.85788]	[0.12017]	[-2.13146]	[-1.37302]	[-4.22524]	[0.15144]
CHPRODD(-2)	1.43E-06	0.053442	3.18E-05	37.56240	-0.182402	8.09E-05
	(9.8E-06)	(0.12312)	(8.7E-05)	(139.715)	(0.10535)	(0.00026)
	[0.14656]	[0.43405]	[0.36433]	[0.26885]	[-1.73132]	[0.31350]
PRF12(-1)	-0.000903	8.506949	0.059529	60356.68	29.49250	1.841044
	(0.00206)	(25.9020)	(0.01836)	(29392.1)	(22.1636)	(0.05430)
	[-0.43832]	[0.32843]	[3.24263]	[2.05350]	[1.33068]	[33.9024]
PRF12(-2)	0.001341	-2.645113	-0.045586	-60629.72	-23.32243	-0.851762
	(0.00204)	(25.6300)	(0.01817)	(29083.5)	(21.9309)	(0.05373)
	[0.65819]	[-0.10320]	[-2.50947]	[-2.08468]	[-1.06345]	[-15.8514]
C	159.2695	1161964.	6358.200	-45498374	266839.6	2262.848
	(92.8360)	(1167453)	(827.440)	(1.3E+09)	(998956.)	(2447.60)
	[1.71560]	[0.99530]	[7.68418]	[-0.03434]	[0.26712]	[0.92452]
FEB	2.008469	68932.71	-1476.630	20093576	-11715.03	95.70069
	(3.65878)	(46010.8)	(32.6104)	(5.2E+07)	(39370.1)	(96.4630)
	[0.54894]	[1.49819]	[-45.2809]	[0.38486]	[-0.29756]	[0.99210]
MAR	-21.66958	106189.2	370.8416	1.47E+08	172614.3	43.01768
	(16.4883)	(207347.)	(146.959)	(2.4E+08)	(177421.)	(434.709)
	[-1.31424]	[0.51213]	[2.52344]	[0.62621]	[0.97291]	[0.09896]
APR	15.87484	-7190.611	-34.64569	-55353175	-31526.98	29.10324
	(9.28367)	(116746.)	(82.7447)	(1.3E+08)	(99896.3)	(244.762)
	[1.70997]	[-0.06159]	[-0.41871]	[-0.41783]	[-0.31560]	[0.11890]
MAY	-1.598916	148663.8	82.65390	80521931	115667.8	164.1981
	(8.46657)	(106471.)	(75.4619)	(1.2E+08)	(91104.0)	(223.219)

	[-0.18885]	[1.39629]	[1.09531]	[0.66648]	[1.26962]	[0.73559]
JUN	10.81161	110775.0	-755.0006	9145450.	25283.83	180.6478
	(6.72435)	(84561.6)	(59.9336)	(9.6E+07)	(72356.9)	(177.286)
	[1.60783]	[1.30999]	[-12.5973]	[0.09531]	[0.34943]	[1.01896]
JUL	-8.555804	168328.1	-715.5640	1.00E+08	104789.3	167.2277
	(11.9271)	(149989.)	(106.306)	(1.7E+08)	(128341.)	(314.456)
	[-0.71734]	[1.12227]	[-6.73120]	[0.58784]	[0.81649]	[0.53180]
AUG	-2.374264	45855.33	-694.8290	60236403	60165.20	98.89127
	(5.79307)	(72850.4)	(51.6332)	(8.3E+07)	(62336.0)	(152.733)
	[-0.40985]	[0.62945]	[-13.4570]	[0.72867]	[0.96518]	[0.64748]
SEP	-7.039959	54477.58	-1277.735	54380865	58620.14	45.35960
	(7.54942)	(94937.2)	(67.2874)	(1.1E+08)	(81235.1)	(199.039)
	[-0.93252]	[0.57383]	[-18.9892]	[0.50479]	[0.72161]	[0.22789]
OCT	-18.13982	34644.24	-583.4921	1.12E+08	107716.2	-28.16001
	(12.2058)	(153493.)	(108.789)	(1.7E+08)	(131340.)	(321.803)
	[-1.48616]	[0.22571]	[-5.36351]	[0.64460]	[0.82013]	[-0.08751]
NOV	-5.328113	-32230.09	-947.1407	19140705	17049.39	-52.76915
	(2.94158)	(36991.6)	(26.2181)	(4.2E+07)	(31652.7)	(77.5541)
	[-1.81131]	[-0.87128]	[-36.1255]	[0.45599]	[0.53864]	[-0.68042]
DEC	-15.76377	59383.88	-268.2511	76630846	95092.88	-44.67153
	(10.6057)	(133372.)	(94.5280)	(1.5E+08)	(114122.)	(279.618)
	[-1.48634]	[0.44525]	[-2.83779]	[0.50634]	[0.83325]	[-0.15976]
T	0.244647	2038.508	9.196729	42227.74	621.3304	3.628900
	(0.14554)	(1830.26)	(1.29721)	(2076873)	(1566.10)	(3.83719)
	[1.68093]	[1.11378]	[7.08963]	[0.02033]	[0.39674]	[0.94572]
R-squared	0.899258	0.763896	0.999913	0.384065	0.919097	0.997278
Adj. R-squared	0.873808	0.704249	0.999892	0.228461	0.898658	0.996590

Sum sq. resids	115.8540	1.83E+10	9203.465	2.36E+16	1.34E+10	80530.26
S.E. equation	1.104317	13887.26	9.842692	15758480	11882.93	29.11506
F-statistic	35.33349	12.80689	45745.04	2.468214	44.96864	1449.992
Log likelihood	-168.1630	-1300.903	-430.6632	-2145.002	-1282.199	-560.8064
Akaike AIC	3.219383	22.09838	7.594387	36.16671	21.78664	9.763440
Schwarz SC	3.800110	22.67911	8.175115	36.74743	22.36737	10.34417
Mean dependent	13.51008	1665.517	14853.99	1168107.	1559.183	271.1702
S.D. dependent	3.108687	25536.03	945.4461	17940532	37327.57	498.5684

Determinant resid covariance (dof adj.)	3.46E+35
Determinant resid covariance	8.51E+34
Log likelihood	-5847.374
Akaike information criterion	99.95623
Schwarz criterion	103.4406

Table D.2. Class III milk price ($/cwt.) ex-post forecast from unrestricted vector autoregression, Jan. 2000-July 2012

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
January	10.0500	9.6766	11.7583	11.9969	12.2260	12.6191	13.3604	13.8170	14.0933	14.8500	**15.3208**	**15.6665**	**16.3982**
February	9.5400	9.4115	11.3597	11.6044	11.7166	12.1660	12.9757	13.4423	13.7016	14.4220	**14.8848**	**15.3113**	**15.9893**
March	9.5400	9.9627	11.7477	12.0761	12.0937	12.5525	13.3618	13.8740	14.1954	14.8096	**15.2597**	**15.7027**	**16.4603**
April	9.4100	10.8104	12.5855	12.7611	12.8472	13.2952	14.0386	14.5742	14.9199	15.4769	**15.9865**	**16.4628**	**17.2011**
May	9.3700	11.4118	13.0075	13.1536	13.3034	13.7936	14.4558	14.9808	15.3895	15.8636	**16.4326**	**16.9333**	**17.6579**
June	9.4600	11.8441	13.2886	13.4705	13.6167	14.1788	14.7177	15.2892	15.8157	16.1636	**16.7652**	**17.2995**	**18.0067**
July	10.6600	11.7790	13.0670	13.2680	13.4058	14.0118	14.5103	14.9734	15.5882	15.9799	**16.5618**	**17.1152**	**17.8458**
August	10.4442	11.8642	13.0105	13.0953	13.2861	13.9781	14.4523	14.8280	15.4512	16.0122	**16.5272**	**17.0099**	
September	10.7434	12.4866	13.4673	13.5278	13.7681	14.5218	14.9056	15.2344	15.8930	16.5282	**17.0151**	**17.4558**	
October	10.3142	12.5042	13.2892	13.4639	13.6721	14.4340	14.7952	15.1474	15.8433	16.4154	**16.8173**	**17.3540**	
November	9.8798	12.0057	12.6002	12.8377	13.0461	13.7883	14.1946	14.5180	15.2347	15.7760	**16.1240**	**16.7254**	
December	10.3888	12.3942	12.8225	13.0479	13.3296	14.1052	14.5329	14.8342	15.5931	16.0975	**16.4250**	**17.0950**	

Table D.3. Class III milk price ($/cwt.) out-of-sample forecast from unrestricted vector autoregression, Jan. 2000-July 2014

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Jan	10.0500	9.6565	11.6151	12.3249	12.1116	12.7291	13.2416	13.7205	14.4952	14.8790	15.3900	15.7999	16.2003	**16.6801**	**17.3794**
Feb	9.5400	9.3875	11.2135	11.8417	11.7413	12.3021	12.8472	13.2851	14.0720	14.4364	14.9937	15.3589	15.8293	**16.3479**	**16.9792**
Mar	9.5400	9.9488	11.5931	12.1030	12.0899	12.6712	13.3140	13.7254	14.4941	14.8954	15.4033	15.7269	16.3189	**16.8401**	**17.3581**
Apr	9.4100	10.8655	12.4136	12.7015	12.7696	13.4034	14.0847	14.4761	15.2721	15.5871	16.1828	16.4457	17.1032	**17.6706**	**18.0892**
May	9.3700	11.4729	12.9561	13.1401	13.1928	13.8626	14.5335	14.9247	15.7217	15.9511	16.6039	16.8736	17.5119	**18.1539**	**18.4741**
Jun	9.4600	11.9531	13.3469	13.5035	13.5736	14.1708	14.8513	15.2317	16.0697	16.3006	16.9630	17.2289	17.7745	**18.5279**	**18.7325**
Jul	10.6600	11.9120	13.2246	13.2667	13.3988	13.8544	14.6483	15.0203	15.8739	16.0764	16.7264	16.9727	17.4950	**18.3102**	**18.4999**
Aug	10.4298	11.9173	13.1953	13.1175	13.3850	13.7889	14.6332	14.9820	15.7756	16.0296	16.7101	16.8926	**17.3632**	**18.1994**	
Sep	10.7385	12.5068	13.6780	13.5632	13.9103	14.2960	15.1049	15.4245	16.2471	16.5661	17.1846	17.3932	**17.8974**	**18.6382**	
Oct	10.2489	12.4655	13.5011	13.3380	13.8639	14.2183	14.9459	15.3459	16.1093	16.4621	16.9579	17.3000	**17.7960**	**18.5120**	
Nov	9.8607	11.8440	12.8306	12.6719	13.2258	13.6285	14.2237	14.7883	15.4076	15.8451	16.2495	16.6466	**17.1396**	**17.8748**	
Dec	10.3643	12.2987	13.1120	12.9335	13.5435	14.0030	14.5080	15.2093	15.6804	16.0871	16.5530	16.9848	**17.4608**	**18.2079**	

Table D.4. Entirety of Johansen Cointegration test for variables in vector autoregressive models

Sample (adjusted): 2000M09 2009M12
Included observations: 112 after adjustments
Trend assumption: Linear deterministic trend
Series: CLASS3 STORD PRODF_N EXPD CHPRODD
PRF12 IMPD
Exogenous series: FEB MAR APR MAY JUN JUL AUG SEP OCT NOV
DEC
Warning: Critical values assume no exogenous series
Lags interval (in first differences): 1 to 2

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.486413	253.9157	125.6154	0.0000
At most 1 *	0.404515	179.2861	95.75366	0.0000
At most 2 *	0.388661	121.2277	69.81889	0.0000
At most 3 *	0.314350	66.11204	47.85613	0.0004
At most 4	0.121070	23.84467	29.79707	0.2071
At most 5	0.055539	9.391085	15.49471	0.3304
At most 6	0.026355	2.991319	3.841466	0.0837

Trace test indicates 4 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.486413	74.62963	46.23142	0.0000
At most 1 *	0.404515	58.05840	40.07757	0.0002
At most 2 *	0.388661	55.11564	33.87687	0.0000

At most 3 *	0.314350	42.26738	27.58434	0.0003
At most 4	0.121070	14.45358	21.13162	0.3290
At most 5	0.055539	6.399767	14.26460	0.5625
At most 6	0.026355	2.991319	3.841466	0.0837

Max-eigenvalue test indicates 4 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegrating Coefficients (normalized by b'*S11*b=I):

CLASS3	STORD	PRODF_N	EXPD	CHPRODD	PRF12	IMPD
-0.060142	-2.11E-05	0.000310	4.52E-08	-0.000178	0.000218	0.000320
-0.198753	-6.14E-05	0.000643	-4.83E-08	-0.000134	0.000599	-0.000252
-0.121470	-0.000106	0.000629	-4.48E-08	5.34E-05	-0.000470	0.000108
-0.011707	4.55E-05	8.89E-05	-1.63E-07	-1.66E-05	9.81E-05	-8.79E-05
0.396863	-1.78E-05	-0.000272	-4.39E-09	8.16E-06	0.000143	1.69E-05
0.382470	2.77E-06	-0.001647	5.99E-09	8.66E-06	-0.002641	-2.73E-05
-0.076898	-3.13E-06	0.001486	8.56E-09	-2.88E-05	-0.001115	-5.50E-06

Unrestricted Adjustment Coefficients (alpha):

D(CLASS3)	-0.229925	0.025387	0.196463	-0.174465	-0.272293	-0.016197	0.057619
D(STORD)	-1757.224	3800.086	6734.644	-1546.297	2336.258	-680.6804	-149.1337
D(PRODF_N)	-2.105326	-0.214928	-0.697346	1.386160	0.990559	0.881482	1.353355
D(EXPD)	-456438.2	1687769.	2622133.	7424635.	-1386333.	-65.52712	-16130.44
D(CHPRODD)	4503.543	5242.559	-1972.548	507.6525	-658.0236	572.6764	711.0411
D(PRF12)	-3.010219	0.632657	5.738119	-4.381194	-5.111252	4.260371	0.402995
D(IMPD)	-3838.424	3097.528	-2426.396	-1445.462	191.5020	311.1777	-150.5418

1 Cointegrating Equation(s): Log likelihood -6658.203

Normalized cointegrating coefficients (standard error in parentheses)

CLASS3	STORD	PRODF_N	EXPD	CHPRODD	PRF12	IMPD
1.000000	0.000350	-0.005154	-7.51E-07	0.002953	-0.003627	-0.005313

	(0.00024)	(0.00313)	(3.4E-07)	(0.00042)	(0.00479)	(0.00081)

Adjustment coefficients (standard error in parentheses)

D(CLASS3)	0.013828
	(0.00663)
D(STORD)	105.6828
	(97.9558)
D(PRODF_N)	0.126618
	(0.06765)
D(EXPD)	27451.06
	(97655.7)
D(CHPRODD)	-270.8516
	(75.3913)
D(PRF12)	0.181040
	(0.17636)
D(IMPD)	230.8501
	(53.1227)

2 Cointegrating Equation(s): Log likelihood -6629.174

Normalized cointegrating coefficients (standard error in parentheses)

CLASS3	STORD	PRODF_N	EXPD	CHPRODD	PRF12	IMPD
1.000000	0.000000	0.011209	7.71E-06	-0.016472	0.001616	0.050738
		(0.02459)	(2.8E-06)	(0.00337)	(0.03827)	(0.00652)
0.000000	1.000000	-46.73942	-0.024173	55.48387	-14.97475	-160.0973
		(78.3241)	(0.00877)	(10.7366)	(121.912)	(20.7810)

Adjustment coefficients (standard error in parentheses)

D(CLASS3)	0.008782	3.28E-06
	(0.02289)	(7.2E-06)
D(STORD)	-649.5959	-0.196379
	(326.795)	(0.10217)
D(PRODF_N)	0.169336	5.75E-05
	(0.23352)	(7.3E-05)
D(EXPD)	-307998.1	-94.04216

	(334949.)	(104.723)
D(CHPRODD)	-1312.826	-0.416793
	(230.881)	(0.07219)
D(PRF12)	0.055298	2.45E-05
	(0.60874)	(0.00019)
D(IMPD)	-384.7929	-0.109411
	(169.106)	(0.05287)

3 Cointegrating Equation(s): Log likelihood -6601.616

Normalized cointegrating coefficients (standard error in parentheses)

CLASS3	STORD	PRODF_N	EXPD	CHPRODD	PRF12	IMPD
1.000000	0.000000	0.000000	1.39E-06	-0.001584	-0.005447	0.010260
			(5.3E-07)	(0.00065)	(0.00740)	(0.00126)
0.000000	1.000000	0.000000	0.002183	-6.595058	14.47245	8.681690
			(0.00077)	(0.93831)	(10.7068)	(1.82374)
0.000000	0.000000	1.000000	0.000564	-1.328192	0.630029	3.611064
			(0.00020)	(0.24471)	(2.79227)	(0.47562)

Adjustment coefficients (standard error in parentheses)

D(CLASS3)	-0.015082	-1.75E-05	6.86E-05
	(0.02599)	(1.3E-05)	(0.00010)
D(STORD)	-1467.653	-0.907604	6.133429
	(333.657)	(0.17193)	(1.31918)
D(PRODF_N)	0.254043	0.000131	-0.001229
	(0.26991)	(0.00014)	(0.00107)
D(EXPD)	-626508.5	-370.9575	2592.434
	(381744.)	(196.713)	(1509.30)
D(CHPRODD)	-1073.221	-0.208478	3.524006
	(262.298)	(0.13516)	(1.03705)
D(PRF12)	-0.641711	-0.000581	0.003083
	(0.68857)	(0.00035)	(0.00272)
D(IMPD)	-90.05864	0.146833	-0.725748
	(185.005)	(0.09533)	(0.73145)

4 Cointegrating Equation(s): Log likelihood -6580.482

Normalized cointegrating coefficients (standard error in parentheses)

CLASS3	STORD	PRODF_N	EXPD	CHPRODD	PRF12	IMPD
1.000000	0.000000	0.000000	0.000000	0.000216	-0.008643	0.007046
				(0.00054)	(0.00620)	(0.00094)
0.000000	1.000000	0.000000	0.000000	-3.771047	9.458791	3.638721
				(0.58403)	(6.68424)	(1.01272)
0.000000	0.000000	1.000000	0.000000	-0.598673	-0.665136	2.308327
				(0.17014)	(1.94727)	(0.29503)
0.000000	0.000000	0.000000	1.000000	-1293.750	2296.883	2310.310
				(226.111)	(2587.83)	(392.078)

Adjustment coefficients (standard error in parentheses)

D(CLASS3)	-0.013039	-2.54E-05	5.31E-05	7.98E-09
	(0.02561)	(1.4E-05)	(0.00010)	(1.9E-08)
D(STORD)	-1449.550	-0.977898	5.995923	-0.000313
	(331.511)	(0.18174)	(1.31485)	(0.00025)
D(PRODF_N)	0.237814	0.000194	-0.001106	-2.79E-07
	(0.26770)	(0.00015)	(0.00106)	(2.0E-07)
D(EXPD)	-713431.9	-33.43574	3252.678	-1.428268
	(327222.)	(179.386)	(1297.84)	(0.24634)
D(CHPRODD)	-1079.164	-0.185401	3.569150	-4.39E-05
	(262.261)	(0.14377)	(1.04019)	(0.00020)
D(PRF12)	-0.590419	-0.000781	0.002693	2.89E-07
	(0.67946)	(0.00037)	(0.00269)	(5.1E-07)
D(IMPD)	-73.13598	0.081123	-0.854288	2.13E-05
	(181.190)	(0.09933)	(0.71864)	(0.00014)

5 Cointegrating Equation(s): Log likelihood -6573.255

Normalized cointegrating coefficients (standard error in parentheses)

CLASS3	STORD	PRODF_N	EXPD	CHPRODD	PRF12	IMPD
1.000000	0.000000	0.000000	0.000000	0.000000	-0.006182	0.005616

					(0.00487)	(0.00073)
0.000000	1.000000	0.000000	0.000000	0.000000	-33.50940	28.62010
					(26.8549)	(4.03836)
0.000000	0.000000	1.000000	0.000000	0.000000	-7.486555	6.274249
					(5.63949)	(0.84805)
0.000000	0.000000	0.000000	1.000000	0.000000	-12444.41	10880.79
					(9055.79)	(1361.78)
0.000000	0.000000	0.000000	0.000000	1.000000	-11.39423	6.624522
					(6.76647)	(1.01752)

Adjustment coefficients (standard error in parentheses)

D(CLASS3)	-0.121102	-2.05E-05	0.000127	9.18E-09	4.86E-05
	(0.04734)	(1.4E-05)	(0.00010)	(1.8E-08)	(2.3E-05)
D(STORD)	-522.3743	-1.019546	5.360030	-0.000323	0.209187
	(627.637)	(0.18014)	(1.34295)	(0.00025)	(0.30999)
D(PRODF_N)	0.630931	0.000177	-0.001376	-2.83E-07	0.000350
	(0.51347)	(0.00015)	(0.00110)	(2.0E-07)	(0.00025)
D(EXPD)	-1263617.	-8.721785	3630.017	-1.422181	-138.7277
	(626679.)	(179.861)	(1340.90)	(0.24484)	(309.520)
D(CHPRODD)	-1340.310	-0.173670	3.748254	-4.10E-05	-1.619172
	(504.362)	(0.14475)	(1.07918)	(0.00020)	(0.24911)
D(PRF12)	-2.618888	-0.000690	0.004084	3.12E-07	0.000788
	(1.28313)	(0.00037)	(0.00275)	(5.0E-07)	(0.00063)
D(IMPD)	2.864138	0.077709	-0.906411	2.04E-05	0.163781
	(349.092)	(0.10019)	(0.74695)	(0.00014)	(0.17242)

6 Cointegrating Equation(s): Log likelihood -6570.055

Normalized cointegrating coefficients (standard error in parentheses)

CLASS3	STORD	PRODF_N	EXPD	CHPRODD	PRF12	IMPD
1.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.001629
						(0.00034)
0.000000	1.000000	0.000000	0.000000	0.000000	0.000000	7.015612
						(1.17562)
0.000000	0.000000	1.000000	0.000000	0.000000	0.000000	1.447447

						(0.21265)
0.000000	0.000000	0.000000	1.000000	0.000000	0.000000	2857.511
						(419.125)
0.000000	0.000000	0.000000	0.000000	1.000000	0.000000	-0.721675
						(0.26337)
0.000000	0.000000	0.000000	0.000000	0.000000	1.000000	-0.644729
						(0.09109)
Adjustment coefficients (standard error in parentheses)						
D(CLASS3)	-0.127297	-2.06E-05	0.000154	9.08E-09	4.85E-05	-0.000141
	(0.06133)	(1.4E-05)	(0.00020)	(1.9E-08)	(2.3E-05)	(0.00028)
D(STORD)	-782.7139	-1.021431	6.480962	-0.000327	0.203292	0.703143
	(811.955)	(0.17990)	(2.59607)	(0.00024)	(0.30973)	(3.72954)
D(PRODF_N)	0.968071	0.000179	-0.002827	-2.78E-07	0.000358	-0.002310
	(0.66270)	(0.00015)	(0.00212)	(2.0E-07)	(0.00025)	(0.00304)
D(EXPD)	-1263642.	-8.721966	3630.125	-1.422181	-138.7283	207.3046
	(811972.)	(179.899)	(2596.13)	(0.24498)	(309.740)	(3729.61)
D(CHPRODD)	-1121.278	-0.172085	2.805180	-3.76E-05	-1.614212	3.491509
	(652.380)	(0.14454)	(2.08586)	(0.00020)	(0.24886)	(2.99657)
D(PRF12)	-0.989425	-0.000678	-0.002931	3.37E-07	0.000825	-0.015392
	(1.63826)	(0.00036)	(0.00524)	(4.9E-07)	(0.00062)	(0.00752)
D(IMPD)	121.8801	0.078571	-1.418853	2.23E-05	0.166476	1.221996
	(451.836)	(0.10011)	(1.44466)	(0.00014)	(0.17236)	(2.07541)

Table D.5. Restricted vector autoregression for the ex-post model, January 2000 to December 2009

Vector Error Correction Estimates
Sample (adjusted): 2000M09 2009M12
Included observations: 112 after adjustments
Standard errors in ( ) & t-statistics in [ ]

Cointegrating Eq:	CointEq1	CointEq2	CointEq3	CointEq4
CLASS3(-1)	1.000000	0.000000	0.000000	0.000000
STORD(-1)	0.000000	1.000000	0.000000	0.000000
PRODF_N(-1)	0.000000	0.000000	1.000000	0.000000
EXPD(-1)	0.000000	0.000000	0.000000	1.000000
CHPRODD(-1)	0.000216	-3.771047	-0.598673	-1293.750
	(0.00054)	(0.58403)	(0.17014)	(226.111)
	[0.39861]	[-6.45689]	[-3.51866]	[-5.72175]
PRF12(-1)	-0.008643	9.458791	-0.665136	2296.883
	(0.00620)	(6.68424)	(1.94727)	(2587.83)
	[-1.39418]	[1.41509]	[-0.34157]	[0.88757]
IMPD(-1)	0.007046	3.638721	2.308327	2310.310
	(0.00094)	(1.01272)	(0.29503)	(392.078)
	[7.50184]	[3.59302]	[7.82410]	[5.89247]
C	-10.31438	1431.742	-13533.53	251821.4

Error Correction:	D(CLASS3)	D(STORD)	D(PRODF_N)	D(EXPD)	D(CHPRODD)	D(PRF12)	D(IMPD)
CointEq1	-0.013039	-1449.550	0.237814	-713431.9	-1079.164	-0.590419	-73.13598
	(0.02561)	(331.511)	(0.26770)	(327222.)	(262.261)	(0.67946)	(181.190)
	[-0.50918]	[-4.37256]	[0.88836]	[-2.18027]	[-4.11485]	[-0.86895]	[-0.40364]

CointEq2	-2.54E-05	-0.977898	0.000194	-33.43574	-0.185401	-0.000781	0.081123
	(1.4E-05)	(0.18174)	(0.00015)	(179.386)	(0.14377)	(0.00037)	(0.09933)
	[-1.80905]	[-5.38084]	[1.32321]	[-0.18639]	[-1.28953]	[-2.09571]	[0.81671]
CointEq3	5.31E-05	5.995923	-0.001106	3252.678	3.569150	0.002693	-0.854288
	(0.00010)	(1.31485)	(0.00106)	(1297.84)	(1.04019)	(0.00269)	(0.71864)
	[0.52285]	[4.56015]	[-1.04178]	[2.50622]	[3.43125]	[0.99938]	[-1.18875]
CointEq4	7.98E-09	-0.000313	-2.79E-07	-1.428268	-4.39E-05	2.89E-07	2.13E-05
	(1.9E-08)	(0.00025)	(2.0E-07)	(0.24634)	(0.00020)	(5.1E-07)	(0.00014)
	[0.41414]	[-1.25425]	[-1.38473]	[-5.79791]	[-0.22233]	[0.56586]	[0.15590]
D(CLASS3(-1))	0.411582	-1473.315	3.506132	-406407.5	806.6566	3.734562	-208.7127
	(0.14250)	(1844.76)	(1.48966)	(1820891)	(1459.40)	(3.78100)	(1008.27)
	[2.88823]	[-0.79865]	[2.35364]	[-0.22319]	[0.55273]	[0.98772]	[-0.20700]
D(CLASS3(-2))	-0.145189	-745.8778	0.802460	-777958.8	-2088.493	-2.216221	1072.152
	(0.11101)	(1437.09)	(1.16047)	(1418504)	(1136.90)	(2.94546)	(785.455)
	[-1.30786]	[-0.51902]	[0.69149]	[-0.54844]	[-1.83701]	[-0.75242]	[1.36501]
D(STORD(-1))	6.21E-06	0.204067	-0.000152	-132.6665	0.167170	0.000115	-0.020537
	(1.1E-05)	(0.14728)	(0.00012)	(145.375)	(0.11651)	(0.00030)	(0.08050)
	[0.54584]	[1.38557]	[-1.27948]	[-0.91258]	[1.43476]	[0.38106]	[-0.25513]
D(STORD(-2))	9.28E-06	0.126686	-8.79E-05	58.62019	0.048117	-9.88E-06	-0.009037
	(9.0E-06)	(0.11626)	(9.4E-05)	(114.759)	(0.09198)	(0.00024)	(0.06354)
	[1.03307]	[1.08965]	[-0.93670]	[0.51081]	[0.52314]	[-0.04147]	[-0.14222]
D(PRODF_N(-1))	-0.012412	162.6703	-0.383918	84647.31	81.66889	-0.015004	2.791219
	(0.01016)	(131.589)	(0.10626)	(129887.)	(104.101)	(0.26970)	(71.9211)
	[-1.22109]	[1.23620]	[-3.61301]	[0.65170]	[0.78451]	[-0.05563]	[0.03881]
D(PRODF_N(-2))	0.010391	-13.74744	0.019460	94104.37	28.93543	0.211199	-44.96695
	(0.00892)	(115.420)	(0.09320)	(113926.)	(91.3095)	(0.23656)	(63.0835)
	[1.16543]	[-0.11911]	[0.20879]	[0.82601]	[0.31689]	[0.89278]	[-0.71282]

D(EXPD(-1))	-6.86E-09	0.000204	2.01E-07	0.035957	-7.61E-07	-1.00E-07	-5.90E-05
	(1.5E-08)	(0.00019)	(1.6E-07)	(0.18973)	(0.00015)	(3.9E-07)	(0.00011)
	[-0.46235]	[1.06005]	[1.29757]	[0.18952]	[-0.00501]	[-0.25439]	[-0.56145]
D(EXPD(-2))	7.38E-09	3.41E-05	8.01E-09	0.013578	-0.000164	2.62E-07	-6.97E-05
	(8.9E-09)	(0.00012)	(9.3E-08)	(0.11420)	(9.2E-05)	(2.4E-07)	(6.3E-05)
	[0.82562]	[0.29451]	[0.08569]	[0.11890]	[-1.79062]	[1.10516]	[-1.10212]
D(CHPRODD(-1))	-2.99E-05	-0.223918	-0.000480	22.96550	0.242777	-0.000729	-0.065820
	(1.8E-05)	(0.23686)	(0.00019)	(233.792)	(0.18738)	(0.00049)	(0.12946)
	[-1.63161]	[-0.94538]	[-2.50786]	[0.09823]	[1.29565]	[-1.50078]	[-0.50843]
D(CHPRODD(-2))	-2.08E-05	-0.047091	-0.000260	-37.99863	0.046988	-0.000505	-0.024429
	(1.1E-05)	(0.14043)	(0.00011)	(138.614)	(0.11110)	(0.00029)	(0.07675)
	[-1.91459]	[-0.33533]	[-2.29339]	[-0.27413]	[0.42295]	[-1.75486]	[-0.31828]
D(PRF12(-1))	-0.005559	50.59117	0.013084	-7704.438	-24.42068	0.909098	31.80565
	(0.00535)	(69.2358)	(0.05591)	(68340.1)	(54.7730)	(0.14191)	(37.8413)
	[-1.03931]	[0.73071]	[0.23402]	[-0.11274]	[-0.44585]	[6.40637]	[0.84050]
D(PRF12(-2))	0.004973	-6.783886	0.075495	74429.49	27.81810	-0.056470	-32.41489
	(0.00509)	(65.9253)	(0.05324)	(65072.5)	(52.1541)	(0.13512)	(36.0320)
	[0.97657]	[-0.10290]	[1.41813]	[1.14379]	[0.53338]	[-0.41792]	[-0.89961]
D(IMPD(-1))	3.68E-05	0.457001	0.000674	376.0214	0.158767	5.89E-05	0.478099
	(3.5E-05)	(0.45203)	(0.00037)	(446.179)	(0.35760)	(0.00093)	(0.24706)
	[1.05273]	[1.01101]	[1.84700]	[0.84276]	[0.44398]	[0.06356]	[1.93517]
D(IMPD(-2))	1.80E-07	0.150853	0.000323	47.66392	-0.038550	-4.47E-05	0.097053
	(1.8E-05)	(0.23670)	(0.00019)	(233.640)	(0.18726)	(0.00049)	(0.12937)
	[0.00983]	[0.63731]	[1.68884]	[0.20401]	[-0.20586]	[-0.09205]	[0.75019]
C	11.96150	-111560.9	631.2897	-18394018	-64100.85	88.56571	-43554.43
	(7.21527)	(93404.3)	(75.4251)	(9.2E+07)	(73893.0)	(191.441)	(51050.8)
	[1.65780]	[-1.19439]	[8.36975]	[-0.19951]	[-0.86748]	[0.46263]	[-0.85316]

FEB	-15.03432	62895.44	-1675.425	-95185664	-39502.48	-218.2280	59527.46
	(9.85871)	(127625.)	(103.058)	(1.3E+08)	(100965.)	(261.579)	(69754.2)
	[-1.52498]	[0.49282]	[-16.2570]	[-0.75560]	[-0.39125]	[-0.83427]	[0.85339]
MAR	-29.01608	311106.9	550.2485	86517597	207250.0	-168.8507	65966.54
	(18.3742)	(237861.)	(192.076)	(2.3E+08)	(188174.)	(487.519)	(130005.)
	[-1.57917]	[1.30794]	[2.86475]	[0.36850]	[1.10137]	[-0.34635]	[0.50742]
APR	20.43427	-147212.8	-276.3602	-1250918.	-45861.79	192.8693	-10015.38
	(9.85395)	(127563.)	(103.009)	(1.3E+08)	(100916.)	(261.453)	(69720.6)
	[2.07371]	[-1.15404]	[-2.68288]	[-0.00993]	[-0.45445]	[0.73768]	[-0.14365]
MAY	-31.35358	198740.1	-236.6120	-94594314	67931.30	-427.7796	124497.7
	(18.2327)	(236029.)	(190.596)	(2.3E+08)	(186724.)	(483.763)	(129003.)
	[-1.71964]	[0.84202]	[-1.24143]	[-0.40603]	[0.36381]	[-0.88427]	[0.96507]
JUN	-2.617090	30092.79	-1209.678	-4201621.	3250.514	-34.90976	28903.98
	(2.11935)	(27435.7)	(22.1547)	(2.7E+07)	(21704.7)	(56.2321)	(14995.2)
	[-1.23486]	[1.09685]	[-54.6014]	[-0.15515]	[0.14976]	[-0.62082]	[1.92755]
JUL	-26.44450	261591.4	-932.3148	30894482	102091.0	-196.7867	69994.61
	(15.2096)	(196894.)	(158.994)	(1.9E+08)	(155765.)	(403.553)	(107614.)
	[-1.73867]	[1.32859]	[-5.86383]	[0.15897]	[0.65542]	[-0.48764]	[0.65042]
AUG	-2.869873	72249.24	-817.0859	97248748	85282.02	92.91627	2836.384
	(8.66568)	(112180.)	(90.5871)	(1.1E+08)	(88746.9)	(229.924)	(61313.1)
	[-0.33118]	[0.64404]	[-9.01990]	[0.87826]	[0.96096]	[0.40412]	[0.04626]
SEP	-14.26064	125319.0	-1327.940	19313298	68181.73	-98.32706	36594.62
	(9.10575)	(117877.)	(95.1874)	(1.2E+08)	(93253.8)	(241.601)	(64426.7)
	[-1.56611]	[1.06313]	[-13.9508]	[0.16599]	[0.73114]	[-0.40698]	[0.56800]
OCT	-18.13207	192862.9	-393.6288	96813795	147472.7	-75.16182	44074.36
	(13.1563)	(170313.)	(137.530)	(1.7E+08)	(134736.)	(349.073)	(93085.9)
	[-1.37821]	[1.13240]	[-2.86213]	[0.57590]	[1.09453]	[-0.21532]	[0.47348]

NOV	-1.266187	3398.097	-846.4619	40529701	34679.30	36.41040	25899.34
	(3.52554)	(45639.4)	(36.8544)	(4.5E+07)	(36105.8)	(93.5423)	(24944.6)
	[-0.35915]	[0.07446]	[-22.9677]	[0.89968]	[0.96049]	[0.38924]	[1.03828]
DEC	-21.77605	208339.8	-71.35540	11547486	115096.3	-213.9622	81993.91
	(11.9488)	(154682.)	(124.908)	(1.5E+08)	(122370.)	(317.035)	(84542.6)
	[-1.82244]	[1.34689]	[-0.57127]	[0.07563]	[0.94056]	[-0.67488]	[0.96985]
R-squared	0.425601	0.756675	0.999813	0.790100	0.976145	0.844744	0.877062
Adj. R-squared	0.222460	0.670621	0.999746	0.715867	0.967708	0.789836	0.833584
Sum sq. resids	103.8202	1.74E+10	11345.11	1.70E+16	1.09E+10	73088.10	5.20E+09
S.E. equation	1.125211	14566.27	11.76244	14377833	11523.51	29.85495	7961.306
F-statistic	2.095104	8.793038	15093.28	10.64352	115.7035	15.38483	20.17247
Log likelihood	-154.6742	-1215.145	-417.5315	-1987.356	-1188.902	-521.8527	-1147.484
Akaike AIC	3.297753	22.23474	7.991635	36.02421	21.76610	9.854513	21.02651
Schwarz SC	4.025922	22.96291	8.719804	36.75238	22.49427	10.58268	21.75468
Mean dependent	0.043304	315.8929	20.93373	-76308.69	283.9911	-9.976429	123.6092
S.D. dependent	1.276065	25380.53	738.6989	26973210	64126.61	65.12350	19515.79

Determinant resid covariance (dof adj.)	2.26E+43
Determinant resid covariance	2.55E+42
Log likelihood	-6580.482
Akaike information criterion	121.7586
Schwarz criterion	127.5354

Table D.6. Class III milk price ($/cwt.) ex-post forecast from the restricted vector autoregression, Jan. 2000-July 2012.

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
January	10.0500	8.1347	8.5023	8.9222	9.9145	10.5776	11.0971	11.5806	12.1840	12.7624	**13.6366**	**14.4166**	**15.0904**
February	9.5400	7.6158	8.0422	8.4544	9.4831	10.1250	10.6683	11.1718	11.7253	12.3140	**13.2400**	**13.9751**	**14.5950**
March	9.5400	7.9452	8.4252	8.8987	9.9275	10.5602	11.1582	11.6599	12.0955	12.7684	**13.6985**	**14.4311**	**15.0706**
April	9.4100	8.6825	9.1627	9.7141	10.7088	11.3734	11.9215	12.4372	12.8853	13.4562	**14.4895**	**15.2157**	**15.8706**
May	9.3700	9.1504	9.5782	10.1859	11.2125	11.7859	12.2830	12.8949	13.4023	13.9376	**14.9636**	**15.6568**	**16.3455**
June	9.4600	9.4395	9.8727	10.4640	11.5985	12.0284	12.5673	13.1527	13.7390	14.2491	**15.2667**	**15.9804**	**16.6228**
July	10.6600	9.2476	9.6264	10.2503	11.4021	11.7968	12.3614	12.9435	13.4746	14.1285	**15.0536**	**15.7315**	**16.3565**
August	10.1300	9.2184	9.5975	10.2064	11.3171	11.7912	12.3016	12.8948	13.4366	14.1991	**14.9965**	**15.6484**	
September	9.7609	9.7566	10.0680	10.8271	11.8581	12.3233	12.8023	13.4311	14.0443	14.8061	**15.5641**	**16.1694**	
October	8.6132	9.6923	10.0691	10.8237	11.8217	12.2580	12.7227	13.3417	14.0698	14.7238	**15.5792**	**16.1294**	
November	8.0013	9.0494	9.4656	10.2987	11.1361	11.6731	12.1024	12.7244	13.4489	14.1360	**14.9892**	**15.6268**	
December	8.6661	9.3296	9.7935	10.6672	11.4489	11.9775	12.4380	13.0478	13.7082	14.4499	**15.2871**	**15.9676**	

Table D.7. Class III milk price ($/cwt.) out-of-sample forecast from the restricted vector autoregression, Jan. 2000- July 2014.

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Jan	10.0500	8.0137	8.7324	9.8087	10.4421	11.2820	12.0532	12.8732	13.5123	14.2174	14.9838	15.7890	16.5999	**17.1030**	**17.8013**
Feb	9.5400	7.5802	8.3270	9.4000	10.0344	10.8921	11.6310	12.4108	13.0741	13.7948	14.5811	15.3828	16.1132	**16.6778**	**17.3460**
Mar	9.5400	7.9930	8.7620	9.8356	10.4859	11.3196	12.1138	12.8112	13.5646	14.2822	14.9654	15.8451	16.5217	**17.0781**	**17.8089**
Apr	9.4100	8.7525	9.5528	10.5802	11.3254	12.1189	12.9622	13.5738	14.3249	15.0973	15.7512	16.6171	17.2243	**17.8518**	**18.6127**
May	9.3700	9.2199	10.0141	11.0323	11.7429	12.5787	13.5148	14.0805	14.7266	15.5592	16.2817	17.0831	17.7080	**18.3056**	**19.0526**
Jun	9.4600	9.4767	10.3809	11.3165	12.0316	12.8827	13.7955	14.4395	15.0424	15.8216	16.6757	17.3482	18.0753	**18.6232**	**19.3585**
Jul	10.6600	9.1606	10.2082	11.0355	11.8417	12.6734	13.5798	14.2745	14.8316	15.5821	16.5218	17.0925	17.8534	**18.4425**	**19.1682**
Aug	10.1300	9.1816	10.2652	10.9580	11.9170	12.6995	13.5145	14.1407	14.7444	15.5883	16.4879	17.0847	**17.8112**	**18.3559**	
Sep	9.7157	9.7992	10.8441	11.4825	12.5221	13.2988	14.0566	14.7074	15.3358	16.2008	16.9847	17.7286	**18.2989**	**18.9498**	
Oct	8.5771	9.8031	10.8053	11.4610	12.4775	13.2047	14.0523	14.6853	15.3596	16.2072	16.9246	17.6588	**18.1827**	**18.8873**	
Nov	7.9677	9.2450	10.2329	10.8821	11.8727	12.5223	13.3835	14.1069	14.7769	15.5552	16.3452	17.0501	**17.5500**	**18.2994**	
Dec	8.5669	9.5709	10.6272	11.2456	12.1725	12.8550	13.6985	14.3793	15.1119	15.8593	16.6321	17.4215	**17.9795**	**18.6040**	

APPENDIX E

Correlation results of the Instrumental Variables, Regression results of 2SLS and 3SLS partial equilibrium models, and forecast results for the partial equilibrium model

Table E.1. Correlation of instrumental variables used in the partial equilibrium model

Variables	FFGD	INC	PMACD	IMP	EXPD	STORD	CPI	INVD	PPC	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	T	PRET(-1)	CONSD(-1)	PWHOLE(-1)	CHPRODD(-1)	CLASS3D(-1)	PRODD(-1)
FFGD	1.0000	0.0703	0.0530	0.0231	0.0489	-0.0729	0.0123	0.1053	0.0446	-0.0333	0.0908	-0.0436	-0.0243	-0.0233	-0.0029	-0.0036	-0.0238	0.0202	0.0046	0.0659	0.0329	0.0063	-0.0404	0.0347	-0.0500	-0.0257	-0.0908
INC	0.0703	1.0000	0.1061	-0.2126	0.0116	0.0195	-0.0073	0.0810	0.4712	-0.0418	-0.0551	-0.0036	0.0296	0.0197	-0.0043	0.0240	0.0114	-0.0169	0.0323	0.0246	0.5466	0.0101	0.0169	0.1494	0.0211	0.0174	0.0153
PMACD	0.0530	0.1061	1.0000	-0.1351	-0.1737	-0.0910	-0.0730	0.0270	0.1269	0.0424	0.0080	0.0261	0.0443	-0.1550	0.1349	-0.0704	0.0799	-0.0892	0.2115	-0.1831	0.2165	0.1801	0.0400	0.1812	0.0412	-0.0987	-0.0088
IMP	0.0231	-0.2126	-0.1351	1.0000	0.0492	-0.1808	0.0493	-0.0168	-0.5750	-0.2099	-0.0408	-0.0767	-0.0409	-0.0446	-0.0336	0.0059	-0.0564	0.1297	0.3030	0.2532	-0.6068	-0.2484	0.0817	-0.1677	-0.0088	0.0497	-0.1141
EXPD	0.0489	0.0116	-0.1737	0.0492	1.0000	-0.0814	-0.0849	0.0793	0.0798	0.0214	0.2318	-0.0303	0.0069	-0.0185	-0.2138	0.0967	-0.1488	0.0452	0.0739	0.1451	0.0470	0.0711	-0.0976	-0.0452	-0.1446	-0.1722	-0.0939
STORD	-0.0729	0.0195	-0.0910	-0.1808	-0.0814	1.0000	-0.0057	0.1848	0.3019	0.1260	0.1106	0.2073	0.1960	0.1554	0.2022	-0.3509	-0.3632	-0.3245	-0.3630	0.2272	0.0472	-0.0134	-0.1705	-0.1029	-0.0122	-0.0313	0.0876
CPI	0.0123	-0.0073	-0.0730	0.0493	-0.0849	-0.0057	1.0000	0.1449	0.0600	-0.1165	-0.1389	-0.0610	0.1238	-0.0209	0.1440	0.0312	-0.0163	0.1012	-0.0941	-0.0631	0.0104	-0.2006	-0.0931	0.4458	-0.0585	0.6617	-0.0541
INVD	0.1053	0.0810	0.0270	-0.0168	0.0793	0.1848	0.1449	1.0000	0.2414	-0.0090	0.1502	0.0409	0.1162	0.0265	-0.1097	-0.1187	-0.1206	-0.1094	-0.0016	0.1211	0.0983	0.1234	-0.0447	0.2865	-0.0202	-0.0951	0.0327
PPC	0.0446	0.4712	0.1269	-0.5750	0.0798	0.3019	0.0600	0.2414	1.0000	-0.2338	0.2136	0.1139	0.2710	0.0420	0.0438	-0.0446	-0.2162	-0.0870	-0.2044	-0.0072	0.8398	0.3662	-0.1527	0.3968	-0.0612	0.0456	-0.0483
FEB	-0.0333	-0.0418	0.0424	-0.2099	0.0214	0.1260	-0.1165	-0.0090	-0.2338	1.0000	-0.0915	-0.0915	-0.0915	-0.0915	-0.0915	-0.0876	-0.0876	-0.0876	-0.0876	-0.0876	0.0206	0.0175	-0.1626	-0.0923	-0.1566	-0.1964	0.1223
MAR	0.0908	-0.0551	0.0080	-0.0408	0.2318	0.1106	-0.1389	0.1502	0.2136	-0.0915	1.0000	-0.0956	-0.0956	-0.0956	-0.0956	-0.0915	-0.0915	-0.0915	-0.0915	-0.0915	-0.0144	-0.0079	-0.3200	-0.0945	-0.4603	-0.0419	-0.4608
APR	-0.0436	-0.0036	0.0261	-0.0767	-0.0303	0.2073	-0.0610	0.0409	0.1139	-0.0915	-0.0956	1.0000	-0.0956	-0.0956	-0.0956	-0.0915	-0.0915	-0.0915	-0.0915	-0.0915	-0.0072	-0.0112	0.5968	-0.0746	0.7054	0.0667	0.6694
MAY	-0.0243	0.0296	0.0443	-0.0409	0.0069	0.1960	0.1238	0.1162	0.2710	-0.0915	-0.0956	-0.0956	1.0000	-0.0956	-0.0956	-0.0915	-0.0915	-0.0915	-0.0915	-0.0915	0.0000	-0.0692	-0.3016	-0.0377	-0.2498	0.0697	-0.1463
JUN	-0.0233	0.0197	-0.1550	-0.0446	-0.0185	0.1554	-0.0209	0.0265	0.0420	-0.0915	-0.0956	-0.0956	-0.0956	1.0000	-0.0956	-0.0915	-0.0915	-0.0915	-0.0915	-0.0915	0.0072	-0.0446	0.1865	-0.0056	0.1594	0.0576	0.2187
JUL	-0.0029	-0.0043	0.1349	-0.0336	-0.2138	0.2022	0.1440	-0.1097	0.0438	-0.0915	-0.0956	-0.0956	-0.0956	-0.0956	1.0000	-0.0915	-0.0915	-0.0915	-0.0915	-0.0915	0.0144	-0.0714	-0.1512	0.0476	-0.2121	0.1080	-0.3302
AUG	-0.0036	0.0240	-0.0704	0.0059	0.0967	-0.3509	0.0312	-0.1187	-0.0446	-0.0876	-0.0915	-0.0915	-0.0915	-0.0915	-0.0915	1.0000	-0.0876	-0.0876	-0.0876	-0.0876	-0.0206	-0.0426	-0.0964	0.0394	-0.0738	0.0249	-0.0046
SEP	-0.0238	0.0114	0.0799	-0.0564	-0.1488	-0.3632	-0.0163	-0.1206	-0.2162	-0.0876	-0.0915	-0.0915	-0.0915	-0.0915	-0.0915	-0.0876	1.0000	-0.0876	-0.0876	-0.0876	-0.0138	0.0430	0.3103	0.0702	0.0175	0.0077	-0.0903
OCT	0.0202	-0.0169	-0.0892	0.1297	0.0452	-0.3245	0.1012	-0.1094	-0.0870	-0.0876	-0.0915	-0.0915	-0.0915	-0.0915	-0.0915	-0.0876	-0.0876	1.0000	-0.0876	-0.0876	-0.0069	0.0530	-0.0934	0.0961	-0.0890	0.0503	-0.2525
NOV	0.0046	0.0323	0.2115	0.3030	0.0739	-0.3630	-0.0941	-0.0016	-0.2044	-0.0876	-0.0915	-0.0915	-0.0915	-0.0915	-0.0915	-0.0876	-0.0876	-0.0876	1.0000	-0.0876	0.0000	0.0772	0.2015	0.0440	0.2269	-0.0447	0.1728
DEC	0.0659	0.0246	-0.1831	0.2532	0.1451	0.2272	-0.0631	0.1211	-0.0072	-0.0876	-0.0915	-0.0915	-0.0915	-0.0915	-0.0915	-0.0876	-0.0876	-0.0876	-0.0876	1.0000	0.0069	0.0514	-0.0316	0.0120	-0.0700	-0.1342	-0.1722
T	0.0329	0.5466	0.2165	-0.6068	0.0470	0.0472	0.0104	0.0983	0.8398	0.0206	-0.0144	-0.0072	0.0000	0.0072	0.0144	-0.0206	-0.0138	-0.0069	0.0000	0.0069	1.0000	0.4979	-0.0303	0.5363	0.0069	-0.0191	0.0129
PRET(-1)	0.0063	0.0101	0.1801	-0.2484	0.0711	-0.0134	-0.2006	0.1234	0.3662	0.0175	-0.0079	-0.0112	-0.0692	-0.0446	-0.0714	-0.0426	0.0430	0.0530	0.0772	0.0514	0.4979	1.0000	0.0222	0.4732	0.0419	-0.3114	0.0254
CONSD(-1)	-0.0404	0.0169	0.0400	0.0817	-0.0976	-0.1705	-0.0931	-0.0447	-0.1527	-0.1626	-0.3200	0.5968	-0.3016	0.1865	-0.1512	-0.0964	0.3103	-0.0934	0.2015	-0.0316	-0.0303	0.0222	1.0000	-0.0212	0.7943	0.0212	0.6174
PWHOLE(-1)	0.0347	0.1494	0.1812	-0.1677	-0.0452	-0.1029	0.4458	0.2865	0.3968	-0.0923	-0.0945	-0.0746	-0.0377	-0.0056	0.0476	0.0394	0.0702	0.0961	0.0440	0.0120	0.5363	0.4732	-0.0212	1.0000	-0.0209	0.2532	-0.0356
CHPRODD(-1)	-0.0500	0.0211	0.0412	-0.0088	-0.1446	-0.0122	-0.0585	-0.0202	-0.0612	-0.1566	-0.4603	0.7054	-0.2498	0.1594	-0.2121	-0.0738	0.0175	-0.0890	0.2269	-0.0700	0.0069	0.0419	0.7943	-0.0209	1.0000	0.0216	0.8797
CLASS3D(-1)	-0.0257	0.0174	-0.0987	0.0497	-0.1722	-0.0313	0.6617	-0.0951	0.0456	-0.1964	-0.0419	0.0667	0.0697	0.0576	0.1080	0.0249	0.0077	0.0503	-0.0447	-0.1342	-0.0191	-0.3114	0.0212	0.2532	0.0216	1.0000	-0.0055
PRODD(-1)	-0.0908	0.0153	-0.0088	-0.1141	-0.0939	0.0876	-0.0541	0.0327	-0.0483	0.1223	-0.4608	0.6694	-0.1463	0.2187	-0.3302	-0.0046	-0.0903	-0.2525	0.1728	-0.1722	0.0129	0.0254	0.6174	-0.0356	0.8797	-0.0055	1.0000

Table E.2. Two stage least squares regression for the ex-post model, Jan. 2000 – Dec. 2009

System: SYSTEM
Estimation Method: Two-Stage Least Squares
Sample: 2000M07 2009M12
Included observations: 114
Total system (balanced) observations 684

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	0.762434	0.212471	3.588413	0.0004
C(2)	0.000100	0.000185	0.541364	0.5885
C(3)	-2.12E-05	2.42E-05	-0.875838	0.3815
C(4)	-1.71E-06	2.15E-06	-0.794907	0.4270
C(5)	0.803763	0.054904	14.63947	0.0000
C(6)	-1.326578	84.68403	-0.015665	0.9875
C(7)	-4.854500	24.24534	-0.200224	0.8414
C(8)	-6.692568	11.08412	-0.603798	0.5462
C(9)	2.588890	2.577074	1.004585	0.3155
C(10)	0.000226	0.000279	0.811307	0.4175
C(11)	-0.375178	0.095051	-3.947131	0.0001
C(12)	-32.86865	13.32221	-2.467207	0.0139
C(13)	95.38466	15.20008	6.275272	0.0000
C(14)	17.71612	17.51143	1.011689	0.3121
C(15)	37.70006	13.77858	2.736136	0.0064
C(16)	19.44443	14.91774	1.303443	0.1929
C(17)	12.86662	12.57810	1.022938	0.3067
C(18)	76.29012	12.89218	5.917552	0.0000
C(19)	35.60717	13.92509	2.557052	0.0108
C(20)	56.28388	15.36051	3.664194	0.0003
C(21)	29.78169	15.45409	1.927108	0.0544
C(22)	7.281140	14.15724	0.514305	0.6072
C(23)	0.034421	0.079126	0.435017	0.6637
C(24)	1.111735	0.448265	2.480083	0.0134
C(25)	-0.280862	0.130362	-2.154468	0.0316
C(26)	4.14E-08	3.63E-07	0.113930	0.9093
C(27)	3.91E-10	7.51E-10	0.519954	0.6033
C(28)	0.987644	0.051685	19.10900	0.0000
C(29)	-3858.451	10448.41	-0.369286	0.7120
C(30)	3884.443	19327.66	0.200978	0.8408
C(31)	-940.9585	1810.824	-0.519630	0.6035
C(32)	-0.101601	0.084750	-1.198831	0.2311
C(33)	-50549.58	7191.990	-7.028594	0.0000
C(34)	75604.28	9617.794	7.860875	0.0000
C(35)	8165.480	7936.566	1.028843	0.3040
C(36)	19861.64	7852.050	2.529485	0.0117
C(37)	-11682.34	5818.393	-2.007829	0.0451
C(38)	-5459.555	7669.966	-0.711810	0.4769
C(39)	6662.190	7762.794	0.858221	0.3911
C(40)	-7242.790	7568.863	-0.956919	0.3390
C(41)	32985.62	7848.481	4.202803	0.0000

C(42)	5809.745	6816.353	0.852325	0.3944
C(43)	33487.40	6597.472	5.075793	0.0000
C(44)	42.10451	41.46285	1.015476	0.3103
C(45)	-0.323897	0.095152	-3.403988	0.0007
C(46)	-2.361776	1.059102	-2.229980	0.0261
C(47)	5.573810	0.594541	9.374977	0.0000
C(48)	5.46E-05	7.90E-05	0.691305	0.4896
C(49)	0.183213	0.057702	3.175142	0.0016
C(50)	0.404442	0.053156	7.608530	0.0000
C(51)	-970.2405	1.81E-10	-5.36E+12	0.0000
C(52)	0.277783	3.94E-14	7.05E+12	0.0000
C(53)	9.741249	1.76E-13	5.54E+13	0.0000
C(54)	-1.39E-13	1.01E-13	-1.384592	0.1667
C(55)	-2.30E-15	1.26E-14	-0.182230	0.8555
C(56)	2.16E-11	2.44E-11	0.885220	0.3764
C(57)	-9.75E-12	1.77E-11	-0.549450	0.5829
C(58)	-3.95E-13	8.43E-12	-0.046902	0.9626
C(59)	-9.12E-12	8.23E-12	-1.108765	0.2680
C(60)	5.78E-12	1.46E-11	0.396695	0.6917
C(61)	3.70E-12	4.85E-12	0.762161	0.4463
C(62)	7.02E-12	8.67E-12	0.809381	0.4186
C(63)	1.73E-11	1.81E-11	0.953583	0.3407
C(64)	9.06E-12	7.22E-12	1.254907	0.2100
C(65)	1.85E-11	1.63E-11	1.133825	0.2573
C(66)	5.05E-12	6.32E-12	0.799215	0.4245
C(67)	-3.13E-13	2.57E-13	-1.219361	0.2232

Determinant residual covariance 5.24E-18

Equation: PRET=
C(1)+C(2)*CONSD+C(3)*FFGD+C(4)*INCD+C(5)*PRET(
-1)
Instruments: FFGD INCD PMACD IMPD EXPD STORD CPI_DAIRYD
INV12_N PPC9_N FEB MAR APR MAY JUN JUL AUG SEP
OCT NOV
DEC T PRET(-1) CONSD(-1) PWHOLE(-1) CHPRODD(-1)
CLASS3(-1)
PRODF_N(-1) C
Observations: 114

R-squared	0.667993	Mean dependent var	3.864991
Adjusted R-squared	0.655809	S.D. dependent var	0.142745
S.E. of regression	0.083745	Sum squared resid	0.764446
Durbin-Watson stat	2.111498		

Equation: CONSD =
C(6)+C(7)*PRET+C(8)*PWHOLE+C(9)*PMACD+C(10)
*IMPD+C(11)*CONSD(-
1)+C(12)*FEB+C(13)*MAR+C(14)*APR+C(15)
*MAY+C(16)*JUN+C(17)*JUL+C(18)*AUG+C(19)*SEP+C(20)*

OCT
+C(21)*NOV+C(22)*DEC+C(23)* T
Instruments: FFGD INCD PMACD IMPD EXPD STORD CPI_DAIRYD
INV12_N PPC9_N FEB MAR APR MAY JUN JUL AUG SEP
OCT NOV
DEC T PRET(-1) CONSD(-1) PWHOLE(-1) CHPRODD(-1)
CLASS3(-1)
PRODF_N(-1) C
Observations: 114

R-squared	0.763329	Mean dependent var	1.576939
Adjusted R-squared	0.721418	S.D. dependent var	45.54358
S.E. of regression	24.03828	Sum squared resid	55472.52
Durbin-Watson stat	2.191025		

Equation: PWHOLE =
C(24)+C(25)*PRET+C(26)*CHPRODD+C(27)*EXPD
+C(28)*PWHOLE(-1)
Instruments: FFGD INCD PMACD IMPD EXPD STORD CPI_DAIRYD
INV12_N PPC9_N FEB MAR APR MAY JUN JUL AUG SEP
OCT NOV
DEC T PRET(-1) CONSD(-1) PWHOLE(-1) CHPRODD(-1)
CLASS3(-1)
PRODF_N(-1) C
Observations: 114

R-squared	0.844330	Mean dependent var	1.716536
Adjusted R-squared	0.838618	S.D. dependent var	0.314274
S.E. of regression	0.126251	Sum squared resid	1.737394
Durbin-Watson stat	1.669060		

Equation: CHPRODD =
C(29)+C(30)*PWHOLE+C(31)*CLASS3+C(32)
*STORD+C(33)*FEB+C(34)*MAR+C(35)*APR+C(36)*MAY+C(
37)*JUN
+C(38)*JUL+C(39)*AUG+C(40)*SEP+C(41)*OCT+C(42)*NOV+
C(43)
*DEC+C(44)*T+C(45)*CHPRODD(-1)
Instruments: FFGD INCD PMACD IMPD EXPD STORD CPI_DAIRYD
INV12_N PPC9_N FEB MAR APR MAY JUN JUL AUG SEP
OCT NOV
DEC T PRET(-1) CONSD(-1) PWHOLE(-1) CHPRODD(-1)
CLASS3(-1)
PRODF_N(-1) C
Observations: 114

R-squared	0.903334	Mean dependent var	1448.333
Adjusted R-squared	0.887389	S.D. dependent var	36027.63
S.E. of regression	12090.02	Sum squared resid	1.42E+10
Durbin-Watson stat	2.112406		

Equation: CLASS3= C(46)+C(47)*PWHOLE+C(48)*PRODF_N+C(49)
*CPI_DAIRYD+C(50)*CLASS3(-1)

Instruments: FFGD INCD PMACD IMPD EXPD STORD CPI_DAIRYD
INV12_N PPC9_N FEB MAR APR MAY JUN JUL AUG SEP
OCT NOV
DEC T PRET(-1) CONSD(-1) PWHOLE(-1) CHPRODD(-1)
CLASS3(-1)
PRODF_N(-1) C
Observations: 114

R-squared	0.956876	Mean dependent var	13.47939
Adjusted R-squared	0.955293	S.D. dependent var	3.197742
S.E. of regression	0.676128	Sum squared resid	49.82930
Durbin-Watson stat	1.524494		

Equation: PRODF_N = C(51)+C(52)*INV12_N+C(53)*PPC9_N+C(54)
*CLASS3+C(55)*PRODF_N(-1)+C(56)*FEB+C(57)*MAR
+C(58)*APR
+C(59)*MAY+C(60)*JUN+C(61)*JUL+C(62)*AUG+C(63)*SEP+
C(64)
*OCT+C(65) *NOV+C(66)*DEC+C(67)*T
Instruments: FFGD INCD PMACD IMPD EXPD STORD CPI_DAIRYD
INV12_N PPC9_N FEB MAR APR MAY JUN JUL AUG SEP
OCT NOV
DEC T PRET(-1) CONSD(-1) PWHOLE(-1) CHPRODD(-1)
CLASS3(-1)
PRODF_N(-1) C
Observations: 114

R-squared	1.000000	Mean dependent var	14756.58
Adjusted R-squared	1.000000	S.D. dependent var	892.0065
S.E. of regression	1.89E-12	Sum squared resid	3.47E-22
Durbin-Watson stat	1.561905		

Table E.3. Class III milk price ($/cwt.) ex-post forecast from the two stage least squares model, Jan. 2000 to July 2012

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
January	10.0500	12.5473	13.4486	13.7190	14.3218	15.1296	15.1483	16.0586	16.0056	15.2225	**15.8483**	**15.5432**	**16.1488**
February	9.5400	12.5627	13.5166	13.8333	14.2330	14.7866	15.1423	15.8796	16.0037	14.6793	**15.5104**	**15.5270**	**15.8782**
March	9.5400	12.7190	13.5877	13.8748	14.4130	14.8886	15.2341	16.0832	15.7668	14.6431	**15.5756**	**15.9823**	**16.0725**
April	9.4100	12.9323	13.6677	13.7689	14.7102	14.9006	15.1870	15.8626	16.0310	14.8625	**15.4231**	**16.2075**	**15.9358**
May	9.3700	13.1833	13.7680	13.8806	15.9350	15.1091	15.4565	15.9872	16.0212	15.1768	**15.7297**	**16.0896**	**16.1300**
June	9.4600	13.3945	13.6366	13.7860	15.3843	14.7442	15.4201	16.2905	16.1134	15.1775	**15.7279**	**15.9548**	**16.1099**
July	10.2906	13.4561	13.6884	14.1343	14.7992	14.9091	15.7386	16.6690	16.5544	15.2684	**15.7222**	**16.0375**	**15.9733**
August	10.7950	13.5461	13.7483	14.4414	14.4385	15.1440	15.6465	16.4529	16.2194	15.3072	**15.5915**	**16.0451**	
September	11.2667	13.4340	13.5873	14.5833	14.1723	14.8304	15.7117	16.1444	15.7244	15.4235	**15.5571**	**16.1336**	
October	11.6810	13.7182	13.7442	14.5371	14.6402	14.9668	16.0039	16.1175	15.5486	15.7087	**15.8443**	**15.9017**	
November	11.8532	13.6374	13.8366	14.3740	14.5678	15.0673	15.6398	15.9688	15.4899	15.3232	**15.5596**	**15.8022**	
December	12.0955	13.5591	13.8519	14.4952	14.6508	14.9772	15.8391	15.7953	15.2551	15.4665	**15.6084**	**15.8254**	

Table E.4. Class III milk price ($/cwt.) out-of-sample forecast from the two stage least squares model, Jan. 2000 to July 2014

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Jan	10.0500	12.4269	13.3386	14.0960	14.2566	14.9432	15.0111	15.9418	16.1103	15.0268	15.4044	15.6786	16.2068	**16.4051**	**16.5320**
Feb	9.5400	12.3288	13.4053	14.1651	14.1430	14.5280	14.9873	15.6698	16.0593	14.4899	15.0777	15.6966	15.8444	**16.2819**	**16.3449**
Mar	9.5400	12.4582	13.4831	14.1039	14.3081	14.6768	15.1850	15.9084	15.8325	14.4501	15.1878	16.0849	16.0531	**16.3988**	**16.5198**
Apr	9.4100	12.6323	13.5847	14.0234	14.6027	14.7568	15.1077	15.8020	16.0918	14.6115	15.0872	16.2738	15.8959	**16.3884**	**16.6420**
May	9.3700	12.9407	13.7799	14.1260	15.8864	14.9890	15.4819	16.0600	16.1274	14.8158	15.4579	16.1754	16.0873	**16.6909**	**16.9828**
Jun	9.4600	13.1450	13.7437	14.0110	15.3542	14.5150	15.4356	16.3793	16.1717	14.8055	15.5194	15.9905	16.1062	**16.5884**	**16.7674**
Jul	10.2676	13.1814	13.7513	14.2636	14.6689	14.6498	15.7678	16.7918	16.5184	14.8741	15.5193	16.0651	16.0626	**16.6857**	**16.7301**
Aug	10.7847	13.2449	13.7855	14.5687	14.3388	14.8824	15.7071	16.6274	16.1985	14.8896	15.4444	16.0871	**16.2786**	**16.7175**	
Sep	11.1922	13.2069	13.7363	14.5986	14.0058	14.6528	15.7044	16.3046	15.6400	15.0146	15.5145	16.1070	**16.1373**	**16.4714**	
Oct	11.5663	13.4330	13.9379	14.5448	14.3833	14.7893	15.9584	16.2262	15.4675	15.1930	15.7903	15.8957	**16.2530**	**16.5347**	
Nov	11.7325	13.3781	14.1700	14.2720	14.2982	14.8681	15.5570	16.0356	15.3524	14.7997	15.6176	15.7765	**16.1968**	**16.3722**	
Dec	11.9445	13.3391	14.2017	14.5050	14.4274	14.8769	15.6761	15.8788	15.0626	14.9167	15.6757	15.8358	**16.2262**	**16.3768**	

Table E.5. Three stage least squares regression for ex-post model, Jan. 2000 to Dec. 2009

System: SYSTEM
Estimation Method: Three-Stage Least Squares
Sample: 2000M07 2009M12
Included observations: 114
Total system (balanced) observations 684
Linear estimation after one-step weighting matrix

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	0.810053	0.202900	3.992377	0.0001
C(2)	0.000102	0.000178	0.569702	0.5691
C(3)	-1.48E-05	2.29E-05	-0.648819	0.5167
C(4)	-2.10E-06	2.04E-06	-1.028232	0.3042
C(5)	0.791264	0.052430	15.09187	0.0000
C(6)	-13.38098	69.70926	-0.191954	0.8478
C(7)	-2.068961	19.90328	-0.103951	0.9172
C(8)	-5.563987	9.789149	-0.568383	0.5700
C(9)	1.102192	2.101801	0.524404	0.6002
C(10)	8.71E-05	0.000225	0.386847	0.6990
C(11)	-0.382736	0.079143	-4.836007	0.0000
C(12)	-31.66720	11.70151	-2.706249	0.0070
C(13)	96.24408	13.14141	7.323725	0.0000
C(14)	17.15621	15.00119	1.143656	0.2532
C(15)	37.46256	12.04228	3.110920	0.0020
C(16)	19.79802	12.90791	1.533790	0.1256
C(17)	14.31335	11.09231	1.290386	0.1974
C(18)	75.36035	11.33781	6.646818	0.0000
C(19)	34.13713	12.18459	2.801664	0.0052
C(20)	59.67898	13.19185	4.523928	0.0000
C(21)	33.98210	13.30189	2.554682	0.0109
C(22)	7.046483	12.27215	0.574185	0.5661
C(23)	0.026349	0.071199	0.370076	0.7115
C(24)	0.604746	0.417054	1.450041	0.1476
C(25)	-0.136988	0.121257	-1.129733	0.2590
C(26)	-4.81E-09	3.36E-07	-0.014291	0.9886
C(27)	-4.88E-11	6.84E-10	-0.071415	0.9431
C(28)	0.959227	0.049476	19.38772	0.0000
C(29)	-6213.869	9222.312	-0.673787	0.5007
C(30)	-2864.794	16253.64	-0.176256	0.8602
C(31)	-38.08481	1514.109	-0.025153	0.9799
C(32)	0.143316	0.070456	2.034130	0.0424
C(33)	-50243.64	6402.430	-7.847588	0.0000
C(34)	76348.94	8385.128	9.105280	0.0000
C(35)	5919.029	7020.006	0.843166	0.3995
C(36)	18007.00	6946.383	2.592285	0.0098
C(37)	-12102.66	5311.406	-2.278617	0.0230
C(38)	-5720.464	6780.484	-0.843666	0.3992
C(39)	17597.14	6788.440	2.592222	0.0098
C(40)	3745.501	6634.414	0.564556	0.5726

C(41)	43764.41	6865.194	6.374825	0.0000
C(42)	16154.16	6056.880	2.667076	0.0079
C(43)	32035.74	5914.052	5.416885	0.0000
C(44)	12.39181	37.60627	0.329515	0.7419
C(45)	-0.315812	0.080806	-3.908287	0.0001
C(46)	-1.875912	0.980860	-1.912518	0.0563
C(47)	4.884590	0.545082	8.961207	0.0000
C(48)	3.60E-05	7.28E-05	0.494178	0.6214
C(49)	0.189494	0.053459	3.544638	0.0004
C(50)	0.476756	0.048826	9.764339	0.0000
C(51)	-970.2405	1.37E-10	-7.07E+12	0.0000
C(52)	0.277783	2.99E-14	9.29E+12	0.0000
C(53)	9.741249	1.33E-13	7.30E+13	0.0000
C(54)	-1.10E-13	7.68E-14	-1.436508	0.1514
C(55)	-4.33E-15	9.59E-15	-0.451985	0.6514
C(56)	1.15E-11	1.85E-11	0.621759	0.5343
C(57)	-7.23E-12	1.35E-11	-0.536307	0.5919
C(58)	3.98E-12	6.40E-12	0.622324	0.5340
C(59)	-1.93E-12	6.25E-12	-0.309570	0.7570
C(60)	7.57E-12	1.11E-11	0.684303	0.4940
C(61)	2.33E-12	3.69E-12	0.631356	0.5280
C(62)	4.67E-12	6.59E-12	0.707967	0.4792
C(63)	1.00E-11	1.38E-11	0.730075	0.4656
C(64)	3.48E-12	5.48E-12	0.635671	0.5252
C(65)	6.82E-12	1.24E-11	0.549647	0.5828
C(66)	-1.20E-13	4.80E-12	-0.025084	0.9800
C(67)	-8.29E-14	1.95E-13	-0.425758	0.6704

Determinant residual covariance 4.60E-18

Equation: PRET=
C(1)+C(2)*CONSD+C(3)*FFGD+C(4)*INCD+C(5)*PRET(
-1)
Instruments: FFGD INCD PMACD IMPD EXPD STORD CPI_DAIRYD
INV12_N PPC9_N FEB MAR APR MAY JUN JUL AUG SEP
OCT NOV
DEC T PRET(-1) CONSD(-1) PWHOLE(-1) CHPRODD(-1)
CLASS3(-1)
PRODF_N(-1) C
Observations: 114

R-squared	0.667484	Mean dependent var	3.864991
Adjusted R-squared	0.655281	S.D. dependent var	0.142745
S.E. of regression	0.083809	Sum squared resid	0.765618
Durbin-Watson stat	2.083966		

Equation: CONSD =
C(6)+C(7)*PRET+C(8)*PWHOLE+C(9)*PMACD+C(10)
*IMPD+C(11)*CONSD(-
1)+C(12)*FEB+C(13)*MAR+C(14)*APR+C(15)

*MAY+C(16)*JUN+C(17)*JUL+C(18)*AUG+C(19)*SEP+C(20)*OCT
+C(21)*NOV+C(22)*DEC+C(23)* T
Instruments: FFGD INCD PMACD IMPD EXPD STORD CPI_DAIRYD
INV12_N PPC9_N FEB MAR APR MAY JUN JUL AUG SEP OCT NOV
DEC T PRET(-1) CONSD(-1) PWHOLE(-1) CHPRODD(-1) CLASS3(-1)
PRODF_N(-1) C
Observations: 114

R-squared	0.760602	Mean dependent var	1.576939
Adjusted R-squared	0.718209	S.D. dependent var	45.54358
S.E. of regression	24.17635	Sum squared resid	56111.62
Durbin-Watson stat	2.149342		

Equation: PWHOLE = C(24)+C(25)*PRET+C(26)*CHPRODD+C(27)*EXPD
+C(28)*PWHOLE(-1)
Instruments: FFGD INCD PMACD IMPD EXPD STORD CPI_DAIRYD
INV12_N PPC9_N FEB MAR APR MAY JUN JUL AUG SEP OCT NOV
DEC T PRET(-1) CONSD(-1) PWHOLE(-1) CHPRODD(-1) CLASS3(-1)
PRODF_N(-1) C
Observations: 114

R-squared	0.840697	Mean dependent var	1.716536
Adjusted R-squared	0.834851	S.D. dependent var	0.314274
S.E. of regression	0.127716	Sum squared resid	1.777949
Durbin-Watson stat	1.600428		

Equation: CHPRODD = C(29)+C(30)*PWHOLE+C(31)*CLASS3+C(32)
*STORD+C(33)*FEB+C(34)*MAR+C(35)*APR+C(36)*MAY+C(37)*JUN
+C(38)*JUL+C(39)*AUG+C(40)*SEP+C(41)*OCT+C(42)*NOV+C(43)
*DEC+C(44)*T+C(45)*CHPRODD(-1)
Instruments: FFGD INCD PMACD IMPD EXPD STORD CPI_DAIRYD
INV12_N PPC9_N FEB MAR APR MAY JUN JUL AUG SEP OCT NOV
DEC T PRET(-1) CONSD(-1) PWHOLE(-1) CHPRODD(-1) CLASS3(-1)
PRODF_N(-1) C
Observations: 114

R-squared	0.894624	Mean dependent var	1448.333
Adjusted R-squared	0.877242	S.D. dependent var	36027.63
S.E. of regression	12622.95	Sum squared resid	1.55E+10
Durbin-Watson stat	2.091336		

Equation: CLASS3= C(46)+C(47)*PWHOLE+C(48)*PRODF_N+C(49)

*CPI_DAIRYD+C(50)*CLASS3(-1)
Instruments: FFGD INCD PMACD IMPD EXPD STORD CPI_DAIRYD
INV12_N PPC9_N FEB MAR APR MAY JUN JUL AUG SEP
OCT NOV
DEC T PRET(-1) CONSD(-1) PWHOLE(-1) CHPRODD(-1)
CLASS3(-1)
PRODF_N(-1) C
Observations: 114

R-squared	0.952090	Mean dependent var	13.47939
Adjusted R-squared	0.950332	S.D. dependent var	3.197742
S.E. of regression	0.712658	Sum squared resid	55.35915
Durbin-Watson stat	1.657099		

Equation: PRODF_N = C(51)+C(52)*INV12_N+C(53)*PPC9_N+C(54)
*CLASS3+C(55)*PRODF_N(-1)+C(56)*FEB+C(57)*MAR
+C(58)*APR
+C(59)*MAY+C(60)*JUN+C(61)*JUL+C(62)*AUG+C(63)*SEP+
C(64)
*OCT+C(65) *NOV+C(66)*DEC+C(67)*T
Instruments: FFGD INCD PMACD IMPD EXPD STORD CPI_DAIRYD
INV12_N PPC9_N FEB MAR APR MAY JUN JUL AUG SEP
OCT NOV
DEC T PRET(-1) CONSD(-1) PWHOLE(-1) CHPRODD(-1)
CLASS3(-1)
PRODF_N(-1) C
Observations: 114

R-squared	1.000000	Mean dependent var	14756.58
Adjusted R-squared	1.000000	S.D. dependent var	892.0065
S.E. of regression	1.98E-12	Sum squared resid	3.81E-22
Durbin-Watson stat	1.400000		

Table E.6. Class III milk price ($/cwt.) ex-post forecast from the three stage least squares model, Jan. 2000 to July 2012

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
January	10.0500	12.1437	13.1208	13.5431	13.8779	14.3996	14.3249	14.8485	14.3954	14.1020	**14.7859**	**14.4124**	**14.6955**
February	9.5400	12.1452	13.2308	13.6672	13.7340	14.0646	14.2305	14.5488	14.4432	13.5767	**14.4997**	**14.4390**	**14.3973**
March	9.5400	12.1843	13.2092	13.6858	13.8197	14.1503	14.1994	14.6794	14.1296	13.4171	**14.3729**	**14.7305**	**14.4682**
April	9.4100	12.3795	13.2554	13.5414	14.1877	14.2973	14.0864	14.5639	14.3609	13.4987	**14.1973**	**14.9685**	**14.2595**
May	9.3700	12.6563	13.3837	13.6014	15.5339	14.3581	14.2616	14.6720	14.3410	13.7599	**14.4233**	**14.8590**	**14.3545**
June	9.4600	12.9246	13.2809	13.4966	15.0793	13.9342	14.1951	14.8954	14.5183	13.8604	**14.4574**	**14.7864**	**14.4029**
July	10.1264	13.0155	13.3930	13.7525	14.3590	14.1339	14.5314	15.3451	15.0026	13.9315	**14.5993**	**14.9111**	**14.3697**
August	10.5983	12.9436	13.4150	14.0939	13.8252	14.3125	14.4366	15.1760	14.6447	13.9579	**14.4245**	**14.9077**	
September	10.9683	12.9243	13.3705	14.2972	13.4879	14.0356	14.4406	14.8797	14.3173	14.1915	**14.4335**	**14.9181**	
October	11.2943	13.0783	13.5075	14.2340	13.8408	14.2124	14.7436	14.6875	14.2505	14.4416	**14.6275**	**14.7428**	
November	11.4341	13.1476	13.6404	13.9474	13.7359	14.2903	14.4342	14.4915	14.2579	14.1690	**14.4520**	**14.5482**	
December	11.6373	13.1496	13.6673	14.1393	13.8526	14.2414	14.5214	14.2175	14.0725	14.2788	**14.4549**	**14.4638**	

Table E.7. Class III milk price ($/cwt.) out-of-sample Forecast from the three stage least squares model, Jan. 2000 to July 2014

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Jan	10.0500	12.0802	12.9907	13.4865	13.9014	14.3918	14.4915	15.2273	15.0035	14.4615	15.0616	14.5793	14.7353	**14.5322**	**14.6583**
Feb	9.5400	12.1041	13.0921	13.5640	13.8407	14.0061	14.5027	15.1010	14.9180	13.9556	14.6976	14.7223	14.4470	**14.3803**	**14.5293**
Mar	9.5400	12.2273	13.1234	13.5852	13.8902	14.0256	14.5124	15.2398	14.5783	13.8315	14.6415	15.0129	14.4394	**14.4069**	**14.4554**
Apr	9.4100	12.3362	13.1306	13.4956	14.2150	14.1926	14.3298	15.0518	14.8287	13.9607	14.4190	15.1779	14.1808	**14.4408**	**14.5061**
May	9.3700	12.5615	13.3131	13.5342	15.5693	14.3315	14.5241	15.1445	14.8529	14.2261	14.5281	15.0355	14.3280	**14.6072**	**14.7294**
Jun	9.4600	12.8943	13.2265	13.3624	15.1445	14.0317	14.4120	15.4535	14.9069	14.0951	14.4930	14.8998	14.4117	**14.6021**	**14.5913**
Jul	10.1021	13.0065	13.2719	13.6265	14.4480	14.2122	14.6365	15.9438	15.3731	14.2036	14.6151	15.0133	14.3942	**14.7059**	**14.7543**
Aug	10.5010	12.9641	13.2638	13.9446	13.8880	14.4345	14.5621	15.8130	15.0686	14.2667	14.5687	14.9726	**14.5185**	**14.6318**	
Sep	10.9292	13.0384	13.2464	14.1430	13.6213	14.1857	14.6581	15.4790	14.6766	14.5070	14.5812	15.0210	**14.5675**	**14.5386**	
Oct	11.1791	13.1730	13.3624	14.1287	13.8889	14.3264	14.9576	15.2644	14.5378	14.7731	14.7386	14.7220	**14.6202**	**14.6320**	
Nov	11.3028	13.1345	13.4894	13.8225	13.7964	14.3957	14.7255	15.0241	14.6379	14.4210	14.6057	14.5190	**14.4230**	**14.4961**	
Dec	11.5841	13.0510	13.5612	14.0323	13.8216	14.3452	14.9251	14.7997	14.4338	14.5675	14.6316	14.4164	**14.4457**	**14.4529**	