

**Effect of Cooperatives Working Together
Herd Retirements on the U.S. Dairy Herd Size**

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Effect of Cooperatives Working Together Herd Retirements on the U.S. Dairy Herd Size

***Abstract:** Cooperatives Working Together (CWT) was a voluntary dairy herd removal program implemented by U.S. dairy cooperatives from 2003 through 2010 in an effort to reduce the aggregate milk supply and increase the All-Milk price received by dairy producers. Through the program participating cooperatives bought out herds from bidding farmers, who were then required to sell their entire herds to slaughter. Payments were financed by a voluntary check-off. The objective of this research is to model and measure the effects of the CWT herd retirement on the number of cows in the U.S. dairy herd, and thus on aggregate U.S. milk production and on milk prices. We use data on quarterly data on cow numbers, milk yields, and CWT removals, and other economic factors by U.S. region to econometrically estimate the effect of the program on total cow numbers. The estimated model allows for both immediate and cumulative effects of the herd retirement program on milk production. We find that CWT's herd retirement program has suffered from significant slippage; every 100 cows removed by CWT reduced the U.S. herd by approximately 50 cows in the same quarter. Such slippage reduces the short-term impact of CWT on milk production and milk prices. Moreover we find that the cumulative effect of CWT removals is quite large; every cow removed by CWT causes a long-run reduction in the U.S. herd by approximately 47 cows. This effect, while perhaps larger than expected, is consistent with dairy herd dynamics; cow removals reduce breeding stock, which magnifies the total effect over time. Thus, while CWT had a small short-run effect on milk production and prices, its effect was much larger in the long term.*

Introduction

U.S. dairy farmers have been subjected to dramatic fluctuations in U.S. and global commodity markets. In particular, booms and busts in milk markets as well as feed prices have squeezed dairy farm margins, causing widespread financial stress among U.S. dairy farms. In response, U.S. dairy cooperatives established the Cooperatives Working Together program in an effort to reduce the nation's milk supply through herd retirements and enhance the U.S. export markets for dairy.

Feed costs are a major input cost to production and vital to producing quality milk. A 16% dairy ration cost producers an average of \$4.86 per hundred-weight in 1990. Following twenty years, feed costs nearly doubled to average \$7.20 per hundred-weight in 2010 (Table 1). This was not consistent with incomes of dairy producers. In respect to the milk prices received to producers, the average all-milk price in 1990 was \$13.68 per hundred-weight, whereas the average in 2010 was \$16.29 per hundred-weight (Table 2). Within the same twenty years, the milk prices increased on average only twenty percent. Just as prices continue to change, the majority of dairy producers have adjusted management practices, altered feeding rations, and incorporated different technologies to increase milk production per cow increasing average yields. Average milk yields nearly doubled in twenty years. Nationally, the average dairy cow in the year 1990 produced 10,930 pounds of milk annually. By 2010 the average production per cow increased dramatically to 21,150 pounds. During the same time, the national herd size has decreased. The total U.S. milking herd in 2010 was 91.5 percent of the herd size of 1990 (USDA).

U.S. milk markets are heavily influenced by dairy policy, including milk marketing orders, price supports, a deficiency payment, import restrictions, and export subsidies. In addition, dairy cooperatives are partially exempt from antitrust law, allowing dairy farmers to collectively market milk. Dairy cooperatives vary in size and function, but have a commonality in that they are all owned by members whom are dairy farmers (USDA). In other efforts, the dairy price supports established in the 1940s. They have seen a degree of variation since their establishment, particularly in the mid-1980s under the Dairy Production Stabilization Act price supports for milk were as high as \$11.60 per hundred-weight in 1986, enduring several changes and ending at \$10.10 per hundred-weight in 1989. The current milk price supports were set under the 2002 Farm Security and Rural Investment Act at \$9.90 per hundred-weight.

Supply control was prominent in the 1980s with first the Milk Diversion program and then later the Dairy Termination program. Through governmental control these programs These supply controls were efforts to reestablish an aggressive support of dairy farmers that had previously been relaxed under the Secretary of Agriculture Earl Butz in the early 1970s (Erba). The climate of the milk market most recently is subject to price volatility and has put pressure on dairy farmers as input costs continue to rise. In order to reduce the impact of market price volatility on dairy farms, the National Milk Producers Federation, an organization representing dairy cooperatives across the country, created Cooperatives Working Together (CWT). From 2003 to 2010 CWT implemented herd buyouts and dairy product export assistance programs in an effort to raise the price of milk. This research models and measures the effect of CWT's herd removal program on the national herd size, total milk supply and ultimately milk prices.

Research Statement

This thesis focuses on the CWT's retirement program and its implications for the U.S. dairy markets through a reduction in number of milking cows. An econometric model is developed to quantify the direct impact of CWT on the size of the U.S. dairy herd, and model results are used to estimate the short- and long-term impacts of the herd retirement program on milk production and milk prices.

Background

Cooperatives Working Together was a program designed and operated by the National Milk Producers Federation to strengthen and stabilize milk prices. CWT programs were run by voluntary funds from dairy producers for the benefit of dairy producers nationally. As of 2010, CWT was funded through contributions of 35 different member cooperatives and other individual producers (Shields). Milk producers producing nearly 70 percent of the milk supply invest 10 cents for every hundred pounds of their milk sold. This pool of funds is used to compensate farmers retiring herds for costs above the culling prices. One division of CWT and the focused of this paper is the Herd Retirement. CWT herd retirements required farmers with accepted bids to cull their entire dairy herd. The program worked with the balance of supply and demand. By retiring dairy herds, the idea is to shift the supply curve by decreasing the supply of milk and ultimately forcing milk prices to rise. The CWT program used funds raised through member contributions to support all their programs including another component called the Export Assistance Program. Today this program exists to help CWT member cooperatives to compete in the world market place, and encourage exportation of United States dairy products by building markets for U.S. dairy products overseas. Ultimately CWT was run by member dairy farmers with the goal to benefit of all dairy farmers of the United States.

The Herd Retirement is a voluntary action by dairy farmers willing to have CWT buy-out their entire producing dairy herd to be permanently removed from production. A farmer wishing to retire a herd was required to submit a bid to the CWT committee that would then review the application and take further action if the bid is accepted. The review, the auditing process, required that an auditor appointed through the National Milk Producers Federation analyze the bid and then review the each farm before bids are accepted. Accepted bids required that farmers

retire by selling their entire dairy herd for slaughter and agreeing not to produce, or allow their farm to be used in any way of producing milk for the duration of five years. Ideally the larger the cooperative member numbers, the larger the pool from which funds to remove herds can be drawn, and therefore more herds that were able to be retired. Conceptually, herd buyouts reduce the supply of milk and thus increase the price of milk.

CWT Herd Retirements began in 2003, and with the exception of 2006, retired herds until its completion in 2010 (Table 3, CWT Summary). Within the programs life and within ten herd retirements a total of 506,921 cows were removed from production and sent to slaughter. Since the collective cooperation has started ten herd retirements have taken place. In removing this number of cows, over 9.67 billion pounds of milk are estimated to have been removed from the nation's total milk production (CWT). Cooperatives Working Together organized herd buyouts according to region. There were five different regions and each varied in its contribution to the buyout and even in the number of herds retired through the program. The five regions were Northeastern, Southeastern, Midwestern, Southwestern, and West. The states of the Northeastern include: Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New Jersey, Delaware, Maryland, New York, and Pennsylvania. West Virginia, North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, Arkansas, Missouri, Kentucky, and Tennessee comprise the states of the Southeastern region. While the states of the Midwest include: Ohio, Indiana, Illinois, Michigan, Wisconsin, Iowa, Minnesota, North Dakota, and South Dakota. The fourth region of the Southwest includes the states: Texas, Oklahoma, Kansas, Nebraska, Colorado, New Mexico, and Arizona. The fifth region of the West includes: Montana, Wyoming, Utah, Nevada, California, Oregon, Washington, and Idaho.

In summary, Cooperatives Working Together and the Herd Retirements were programs established as an attempt at supply control within the dairy market in efforts to increase prices received to dairy producers. The program was voluntarily funded and required a tax of 10 cents per every hundred pounds of milk sold by member producers. This pool of funds was used to monetarily compensate producers who were accepted by the program and chose to removal all production cows from the farm premise and promising not to milk or use their facilities for production for at least five years. Through a total of ten herd removals in the span of seven years CWT was able to retire over 500,000 dairy cows.

Literature Review

Cooperatives Working Together Herd Retirement program is not the first supply management program to be implemented in the United States. In the 1980's volatility in milk prices hindered the viability of dairy producers. Two federal programs, the Dairy Termination (DTP) and Milk Diversion (MDP) programs were implemented during this time in order to reduce milk supply and raise milk prices. While these policies differ in important ways from the CWT Herd Retirement program, they were created with similar objectives and may shed some light on the economic consequences of the CWT program. In this section we review the literature relevant to these previous programs to obtain a broader understanding of relevant research and findings.

A Review of Some 1980's Dairy Programs

Helmberger and Chen (1994) elaborate on the finding of Dixon, Bausell, and Smith recognizing that the climate of the dairy market in the mid-1980s was a product of increased price support prices. Previously, from 1966 to 1979 the national milk supply had actually been decreasing. The percentage increase in the national blend price in 1979 and 1983 rose 2% and 21.6% respectively from increased expenditure in the price supports. Supply management programs such as the Milk Diversion Program and the Dairy Termination Program were ultimately a result of mismanagement of the dairy price support program, providing ample incentive for producers to increase milk supply and resulting in excess capacity. These supply management programs were an attempt to curb excess capacity.

The Milk Diversion Program was created under the Dairy Production Stabilization Act of 1983 (Lee pp. 193). A portion of the Act was a 15-month voluntary milk diversion program which called for producers to reduce their milk marketing by 5-30% and only sell cattle for slaughter or to others in the program (Glaser pp. 2-3). Under the provision of this program producers subscribed to curb milk supply by nearly 7.5 billion pounds of milk. The Milk Diversion Program was orchestrated through governmental controls, and required a tax of 50 cents per hundred-weight of milk from all producers to fund the program for its duration, December 1983 to March 1985. This Act also lowered price supports for milk and required a dairy products promotion. The reasoning behind lowering milk support prices was to decrease the incentive for farmers to increase milk production. Dixon, Susanto, and Berry concluded that this program effectively removed milk output in short run only.

In 1986, Congress established the Dairy Termination Program as a provision of the 1985 Food and Security Act and was also designed to reduce milk supply. The program was designed as a voluntary, government-funded program. Much like the operations of Cooperatives Working Together, DTP provided cash payments for dairy producers willing to stop producing milk. Also the abandoned dairy farm facilities must not be used or sold for dairy production. Dairy Termination program required to quit and cease to produce or use any facilities for milk production for at least five years. Studies show that producers who chose to participate chose not to enter back into production even after the retirement period expired (Gale pp. 123). The DTP was a one-time program that spanned 17 months in length, ending in August 1987 (Dixon, Susanto, and Berry). The DTP was financed through a compulsory tax of 40 cents per hundred-weight milk sold of all U.S. milk producers from April 1 to December 31, 1986, and then

changing to 25 cents per every hundred-weight of milk sold from January 1 to September 31, 1987 (Glaser pp. 3). Along with the herds that were retired under the DTP program, nearly 11.3 billion pounds of milk were also removed from production reducing the short term milk supply.

Bausell, Belsley, and Smith (1992) analyzed the economic effect of the Milk Diversion and Dairy Termination programs. The paper analyzes the short and long term effects of each of the programs. This model also recognized major differences in production regionally and created variables to account for the different production of different regions. The model, analyzed through two different equations helped discover that the Milk Diversion Program had a short-term impact the Dairy Termination Program had a more long-term impact. However, under the DTP it was found that the five-year ban had little impact as herd size began increasing to pre-DTP equilibrium levels after the final herd removals. Helmberger and Chen (1994) recognize that the dairy market is not absent from other factors such as the price support and ultimately the milk-feed price ratio reflecting the milk margins received to farmers. The study indicates that the national herd size would have fallen by 2.2% from 1979 to 1983 as a result of dramatically decreasing milk margins. The milk-feed price ratio fell from \$1.41 in 1979 to \$1.16 in 1984, a decrease of approximately 18% in a five-year time span. Conclusively, the price support program increased expenditures raising the blend price to \$12.52 after 1984 from the previously set \$10.54. Milk margins would have increased and market indicators would have spurred the national dairy herd size to increase.

The study by Bausell, Belsley, and Smith also found that the DTP suffered from slippage: the U.S. dairy herd shrunk by less than the number of cows removed by the program. Slippage could occur if program participants intended to exit the industry regardless of the programs

existence. Therefore the program would not actually be removing any more cattle over net normal culling. Slippage also exists in the response of nonparticipants potentially culling fewer cattle than would have previous to the programs operations (Bausell, Belsley, and Smith, 1992). Slippage has important implications for the economic effects of the program. In particular, slippage reduced the impact of DTP on aggregate milk production and, thus, on milk prices and economic welfare of dairy farms.

An Economic Analysis of Dairy Herd Dynamics

The changing dairy herd size and increasing average milk production per cow are the derivative of the changes in aggregate milk production (Bryant, Outlaw, and Anderson). According to a study by Chavas and Klemme (1986) the short run supply of milk was found to have a small elasticity appearing nearly inelastic and ranging from 0.07 and 0.16 (Hammond, Wipf, Houck, and Chen, Hutton and Helmberger). This varied from the long term response of milk supply which has been theorized to have an even wider range of elasticities, ranging from 0.14 (Hammond), 2.20 (Dahlgram), and 2.53 (Chen). This variation in the supply responses on the long and short term reflect the importance of understanding the dairy herd dynamics in modeling total milking cow numbers.

A dynamic model of the aggregate dairy herd's size and age structure was developed, and could constitute for U.S. milk production when combined with an analysis of milk cow productivity in the study of Chavas and Klemme (1986). Previous studies have shown that the dynamics of the dairy herd plays an essential role in the aggregate milk production and ultimately milk prices. The model includes several variables such as the lagged female portion

of the dairy herd, 50% of all live calves to be born as heifers, the number of two-year old replacement dairy heifers, while assuming a 12-month calving interval, culling or retention rates. The retention rate or culling portion is a multi-faceted reflection of the economic situation, including the milk prices, feed prices, slaughter prices, and even the cows' productivity in respective life and production stages. One statement in the literature explains that increasing milk prices have a negative effect of slaughter rates in the short-run and increase the future herd size. Meanwhile sustained feed cost increases have negative affects of heifer numbers and producing cow numbers. The model also incorporates increasing milk productivity per cow accrediting it to genetic improvements and management decisions made to replace older producing cows with younger more productive dairy cows. Congruently lower feed prices lower culling rates, increase feed demand and also milk production per cow. Conclusively, the milk price, feed price, animals' age, and slaughter prices all affect the real value of producing dairy cattle.

The variables of the model relative to the conditions of the 1980's dairy climate indicate the economic situation gave dairy producers incentive to increase milk production by about 4% per year. Of this increase, 1.8% is contributed to by increased productivity while the larger 2.2% is accredited to an increased herd size. This situation is relative to the increasing milk-feed ratio, reaching its highest value in 1982 (Chavas and Klemme). It was largely believed that this increasing milk production was unmatched by milk demand and artificial created under an inflated, un-equilibrium milk market and increased milk price supports. Relevantly, in the research of Brynat, Outlaw, and Anderson (2007) found that the long-run equilibrium demand

and herd size was halfway achieved in 10.5 years in response to a sustained change in a supply determinant of the Milk Income Loss Contract policy analysis.

Short-run adjustments in milk production are a product of increasing productivity per cow, while the long term impact on milk supply is relevant to the changing size of the producing dairy herd. The research of Chavas and Klemme concludes that the economic indicators have strong effects on dairy herd dynamics. For example dairy farmers react strongly to market prices through management decisions that affect the size and productivity of their individual dairy herds and collectively the entire U.S. dairy herd. The long-run effects of policies in the 1980s that encouraged an expansion of the dairy herd had a costly impact and a difficult fix. Reducing the herd size to previous numbers is difficult and would be costly to producers because of the compounding nature of the dairy cow population. Congruently, a study of the economic analysis of dairy herd dynamics as impacted by the MILC program found similar results, the long-run milk supply responses were substantially larger than the short-run responses (Bryant, Outlaw, and Anderson).

Conceptual Model of the U.S. Dairy Herd

The number of cows in the U.S. dairy herd is the result of herd management decisions made by farmers in response to economic conditions, as well as biological factors related to a dairy cow's production life and genetics. Determinately the conceptual model requires total cow numbers to be some function of several key factors including the number of that milked in the last quarter, the number of cows slaughtered or removed through CWT actions within the same time period, expenses of last quarter and congruently incomes of last quarter, as well the costs and benefits of policy implications on dairy producers.

The economical conditions surrounding dairy production and effecting major costs and benefits to dairy farmers have a major impact on producers' decisions to produce milk. The incomes from milk production are an overarching variable that directly or indirectly impact production decisions made for dairy operations. The costs associated with dairy businesses also have a large impact on production decisions producers must make. Feed costs are a major input cost and vital to milk production. Utilizing adequate nutrition the livestock daily diet is essential to produce both quality and quantified amounts of milk which in turn impact incomes of producers. For the purpose of this model, we expect that as feed costs increase total cow numbers decrease in response. Congruently, as incomes from milk increase we hypothesize that total cow numbers would increase in response. The motivation of this study is central to the more recent economic condition characterized by price volatilities in both feed costs and milk prices.

In our estimated equation time series data and lagged variables are used as we expect each animal to live multiple periods. This aspect introduces positive serial correlation in the data

and results which in consistent with our knowledge of dairy cow biology. Modeling the effects of CWT herd removals is prominent in the long-run estimations as we assume each cow to produce a heifer calf at every other calving, and each calf's eventual production two years later at her first calving and the start of her lactating life. Furthermore milk yields progressively increase as feeding practices adjust to accommodate the evolving genetics of the national dairy herd (Figure 4). The implications of increasing production per cow additionally compound the impact of each CWT herd retirement on the future herd size and total production. Removing cows within this quarter also removes her heifer calf to be born two lactations in the future and her potentially greater production after her first calving. We can presume that each generation will continue to increase milk yields. In 1990 the average cow produced 3,620 pounds per quarter year, this has increased dramatically by an average of 1,660 pounds of milk per cow in the span of twenty years for in 2010 the average cow in the U.S. was producing 5,290 pounds per quarter (Table 11). This increase is significant in understanding the balance between the milk supply and relatively consistent demand for milk. Therefore we hypothesize that the biological factors such as increasing milk production per cow have potential to increase the total supply of milk which could have a negative effect on the total number of cows producing nationally all in reflection of creating the balance between milk supplied and demanded.

The research model attempts to quantify the effects of CWT herd removals on the short-run and long term national dairy herd size. CWT's Herd Retirement efforts in supply control we expect to decrease total numbers of cows. The number of cows removed through herd retirements was small, representing approximately two percent of the national herd size in its largest retirement of 2009 (Table 4). Building on previously stated hypotheses we expect that these removals, although small in comparison to the larger total number or producing cows in the

U.S. have a compounding effect. Therefore the immediate short-run impact of CWT removals will be small on total herd size, total milk supply, and the price received to dairy producers. However, the cumulative effects of removing one cow within a given quarter accumulate to have a larger impact in the long term national herd size.

Bryant, Outlaw, and Anderson (2007) built an equation to measure the milk supply response to MILC payments. Aspects of their model in respect to cow numbers are incorporated into the model we made for this study. We expect the effect of the variable of interest, CWT removals on the national dairy herd will be something less than one. That is, we expect there to be a significant amount of slippage. In this study, slippage is the difference between the expected and actual number of cows removed. This concept has been incorporated into this study after reviewing an analysis of different dairy programs and policies in the 1980s (Bausell, Belsley, Smith, 1992, pp. 608). Including slippage in our hypothesis implies that we expect that for every single cow removed through CWT the actual national herd size falls by something less than one in the same quarter. Quarterly dummy variables are included to adjust the intercept along with regional dummies signifying the five different regions of CWT herd removals. Thus a general expression of the number of dairy cows in any period (t) is:

$$(1) \text{ Cow numbers} = F(\text{cows}_{t-1}, \text{CWT removals}_t, \text{milk price}_{t-1}, \text{feed price}_{t-1}, \text{cull price}_{t-1})$$

Econometric Model

Building on the conceptual model, we specify an empirical model to test our hypotheses on cow numbers. We posit the following econometric model (Table 5, Variable descriptions):

$$(1) \text{COW}_{i,t} = \beta_0 + \beta_{\text{SPR}}\text{SPR}_t + \beta_{\text{SUM}}\text{SUM}_t + \beta_{\text{FALL}}\text{FALL}_t + \beta_{\text{NE}}\text{D}_{\text{NE},t} + \beta_{\text{SE}}\text{D}_{\text{SE},t} + \beta_{\text{MW}}\text{D}_{\text{MW},t} + \beta_{\text{SW}}\text{D}_{\text{SW},t} \\ + \beta_{\text{lagcow}}\text{COW}_{i,t-1} + \beta_{\text{CWT}}\text{CWT}_{i,t} + \beta_{\text{AMP}}\text{AMP}_{i,t-1} + \beta_{\text{feed}}\text{FeedP}_{i,t-1} + \beta_{\text{cull}}\text{CullP}_{i,t-1} + \beta_{\text{MILC}}\text{MILC}_{i,t-1} + \\ \varepsilon_{i,t}$$

Based on our previous discussion of slippage, we use the econometric model in (1) to test the hypothesis that there is no slippage in cow numbers with the use of CWT removals. Specifically we test:

$$\begin{aligned} H_0: \beta_{\text{CWT}} &= 1 \\ H_A: \beta_{\text{CWT}} &< 1 \end{aligned}$$

Our null hypothesis representing everything we do not expect is stated that for every one cow that CWT removes, the national herd size would fall by one cow. The alternative hypothesis implies slippage. That is for every cow that CWT removes its actual effect as seen in the following quarter is less than one. This is consistent with our hypothesis that slippage does exist.

Data

Quarterly data is used to account for the seasonal nature of milk production. We also use data starting in 1990 and spanning until 2010. CWT's herd retirements existed from 2003 to 2010, and occurred in only ten quarters of the duration of time. Data was also recorded by region. In this study all price information was identical amongst regions, while reported cow numbers and CWT removals varied between all the different regions. This research aims to find the effect that CWT removals have on the number of cow milking nationally. In creating an econometric model, we used cow numbers ($COW_{i,t}$) as the dependent variable upon which all other variables were regressed. The number of milking cows was collected quarterly from 1990 to 2010. The total number of dairy cows producing has decreased on average since 1990 (Figure 2). Ending 2010 there were 9.96 million less milking cows that had been producing in 1990. This is an 8.5% difference in herd size seen in twenty years.

Seasonality was also incorporated into the model through the use of quarterly dummy variables. Amongst the data are three dummy variables to account for spring (SPR_t), summer (SUM_t), and fall ($FALL_t$). CWT removals and cow numbers varied amongst the regions. Therefore regional dummy variables have been added to the equation to adjust the intercept for the different regions. Five regions are included in the CWT model and listed previously include the Northeast, Southeast, Midwest, Southwest, and West. We chose to divide the nation into these sections based on the regional removals that were set by CWT. Dummy variables in the model were incorporated to include the Northeast (NE_t), the Southeast (SE_t), the Midwest (MW_t), and the Southwest (SW_t). Collectively these seasonal and regional dummy variables work together to create the intercept of the model.

According to our results, account for 98.9% of the variation from quarter to quarter are the number of cows lagged ($COW_{i,t-1}$). We would expect lagged cow numbers to closely follow the trend in cow numbers. Lagged cow numbers are lagged just one period, or one quarter of a year. This is done to be consistent and reflect the seasonality of milk production. This also introduces a time series characteristic of the data used in this model. We included this variable because the biology of a cow inclines her to multiple consecutive time periods within this model.

Central to this study was the CWT variable which represented our variable of interest. It was regressed on the number of cows to find its effect and to discover how well it explained the degree of variation in the number of milking cows changing from quarter to quarter. As stated earlier and evident in the graph below, CWT removals varied amongst different periods and from region to region depending on the number of bids accepted. CWT herd retirements were largest in 2009 removing over 200,000 milking cows from production, and absent in 2006 when no herd retirements existed. The graph below shows the number of milking cows in the U.S., the number of cows removed through CWT in the years 2003 to 2010, and also the ratio of CWT removals on total milking cow numbers (Table 4, CWT of milking cows). The CWT removals range from 0.34% in 2010 to 2.19% in 2009 of the total U.S. milking herd. CWT herd retirements effect on the total number of cows milking in the U.S. is actually significantly smaller due to a large amount of slippage.

Several variables have also been included in the model to account for average prices either paid or received by dairy producers. In this model, the data in this section does not vary amongst the different regions. Included in the model are feed prices ($\text{FeedP}_{i,t-1}$), cull cow prices ($\text{CullP}_{i,t-1}$), the all-milk price ($\text{AMP}_{i,t-1}$), and MILC ($\text{MILC}_{i,t-1}$) payments made to dairy producers. The feed prices represent a cost to dairy producers, whereas the all-milk price, MILC payments, and cutter prices represent income for dairy producers. These factors represent the core of economics as farmers see it, in terms of costs and benefits. Each variable is also lagged in this equation because the effects they have on total cow numbers will be seen in the following quarter. We expect each of these variables to be significant in the choices that producers must make to cull or keep producing cattle. We would expect as the benefits increase total cow numbers decrease at a lesser rate. We expect the reciprocal to be true of costs. As costs increase, the number of cows could be expected to decline at a faster rate. All-milk price, MILC payments, and cull prices all increase incomes received to dairy farmers. As previously graphed, all-milk price is seeing more dramatic high and low swings in most recent years.

Dairy farmers have not only seen a volatile milk price, but have also been experiencing steadily increasing expenses. Feed prices ($\text{FeedP}_{i,t-1}$) which serve as a major cost to dairy producers have also become typified by the extreme high and dramatic drops (Figure 3). None the less, the dairy ration and its components are essential to milk production. For the purpose of this study a 16% (protein) dairy ration was used to account for the feed price (USDA). The feed price associated is lagged because we expect that feed prices in this quarter will affect the milk production of next quarter. The figure below provides a visual of the trend in feed prices typical of a 16% dairy ration from quarterly, 1990 to 2010.

Results and Implications

Parameter estimates and their associated p-values are found through a regression analysis (Table 6). We find that most coefficient estimates are as we would expect them. Lagged feed prices and also CWT removals have a negative effect on herd size. All-Milk prices and MILC payments both have a positive effect on total cow numbers as we would expect. Further, we find strong serial correlation in cow numbers, as expected. The coefficient on cull cow prices are the only parameter we estimated with an unexpected sign; we would expect higher cull prices to encourage herd reductions and therefore have a negative effect on total herd size. But this estimate is statistically indistinguishable from zero at the 5% significance level. All other variables are significant at the 5% level.

With regards to CWT, the estimated CWT coefficient is -0.491 with a p-value of 0.000. We reject the null hypothesis, $H_0: \beta = 1$. This estimate is consistent with a significant degree of slippage in the CWT herd retirement program. For every 100 cows removed through CWT in a quarter we estimate that the national herd size decreases by approximately 49 cows in the same quarter. Our estimate is consistent with Bausell, Belsey, and Smith who found a 10% associated with the dairy herd retirement of 1986.

The small immediate effect of CWT on national herd size suggests a significant amount of slippage in the short-run. As discussed above, slippage may result from supply response to favorable changes or anticipation of favorable changes in prices and market conditions. For example, Erba and Novakovic (1995) found that producers under the Milk Diversion program felt no need to continue at reduced production levels and immediately increased production at or

higher than previous production levels. Slippage could also be a result of removing cows that would have been culled even in the absence of the CWT herd retirement program.

The estimated slippage rate significantly reduces the effect of the program on the size of the U.S. dairy herd, and thus on milk production and milk prices. For example, in the most active round of herd retirements (second quarter 2009) CWT bought out 101,040 cows. However, due to slippage we calculate the actual net reduction in the total U.S. herd size in the immediate quarter was approximately 49,600 cows.

Slippage similarly reduces CWT's impact on aggregate milk production. I use average yields to calculate the short-run impact on U.S. milk production (Table 7). Because the dairy herd shrinks by only 49% of CWT removals, CWT reduces milk production by only 49% of the production of retired cows. Slippage also dilutes the impact of CWT on aggregate milk prices. In table 8 we report the price impact for a range of plausible values for the elasticity of demand for milk. The percent changes in price vary with the range of elasticity from 0.7% (for demand elasticity of -0.8) to 5.4% (for demand elasticity of -0.1). Within the quarter of heavy retirements, in the second quarter of 2009 we apply the range of price elasticity to the price received to dairy producers, \$11.60/cwt, to find that CWT removals potentially raised All-Milk price by between \$0.08/cwt and \$0.62/cwt in the same quarter (Table 9).

Previous studies by Brown analyze the effects of CWT's Herd Retirements on All-Milk prices received by dairy producers between 2003 and 2007. These results by Brown are published and represent the CWT's claimed impact on milk prices (Table 10). The econometric model used in published results of the CWT impact makes several assumptions in regards to CWT's Herd Retirement, including: incorporates eight herd retirements, explicit accounting of CWT cows removed and the loss of their future heifer calves, supply response from higher

prices, and as well bred heifers removed through retirements are included (Brown). In our research we calculate the short-run impact of CWT's actual ten herd removals on returns made to producers' investments and find that Brown's calculated effect on milk prices fall within the range of results we expect given plausible price elasticities of milk. For example, in the first year of removals, 2003 which we assume is devoid of compounding effects of CWT removals, we find that within a price elasticity range -0.1 to -0.8 we find that CWT's impact of prices received to dairy farmers falls between \$0.26/cwt and \$0.03/cwt. Brown's analysis of CWT's impact also shows the cumulative effects as each herd retirement adds to the impact on the dairy market from periods previous. We hypothesize that the effect of removing one cow today accumulates over time and heifers unborn to removed cows this period will be absent from production in future periods and as will the heifers of the offspring of the initially removed cow, and so on. The effect of removing one cow today grows and compounds with each consecutive quarter and accelerates with every herd removal. However, where we assume CWT removals compound over time, Brown calculates that the impact of each removal diminishes with each passing period.

While the short-run impact of CWT is small. Our study also finds that the long-run effect of removing 100 cows through CWT in this quarter reduces the national herd size by nearly 47 cows in the future. The research question resonates in whether the associated price responsiveness is sufficient enough to exceed the initial investment if producers and effective enough to compensate in a timely manner. Particularly the previous study of supply controls such as in the analysis of some 1980's dairy programs, Bausell, Belsey, and Smith found similar slow responses in cow numbers. Supply control programs also failed to be as efficient as

lowering support prices in achieving substantial reductions in herd sizes (Bausell, Belsey, and Smith).

The long lasting effect though can be explained by compounding factors, such as dairy herd dynamics that prove removing one producing cow today is magnified over time. Our results suggest that the CWT herd buyouts may be an imperfect tool for managing short-run price volatility in dairy markets. Further, these CWT reductions continue to influence the total U.S. herd size and total milk production in the future when reduced cow numbers may not be desirable. Overall CWT had a small short-run impact on the total number of milking cows and the total domestic milk production while its long term effect was much larger.

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Tables and Figures

Table 1. Feed cost, %16 dairy ration (\$/cwt), 1990-2010				
<i>Year</i>	<i>Minimum</i>	<i>Maximum</i>	<i>Standard deviation</i>	<i>Average</i>
1990	4.55	5.19	0.26	4.86
1991	4.29	4.67	0.19	4.49
1992	4.08	4.66	0.25	4.37
1993	4.29	4.91	0.25	4.60
1994	4.48	5.33	0.45	4.93
1995	4.59	5.25	0.28	4.92
1996	5.38	6.78	0.72	6.15
1997	5.34	6.02	0.32	5.62
1998	4.20	5.31	0.53	4.73
1999	3.75	4.22	0.24	4.01
2000	3.79	4.25	0.20	4.04
2001	4.30	4.52	0.09	4.41
2002	4.40	4.91	0.26	4.68
2003	4.65	4.98	0.15	4.80
2004	4.58	5.92	0.55	5.20
2005	4.49	4.88	0.19	4.69
2006	4.62	5.63	0.43	5.04
2007	6.29	7.20	0.38	6.81
2008	8.34	9.99	0.91	9.19
2009	6.81	7.86	0.57	7.30
2010	6.79	8.05	0.59	7.20

Source: USDA, "16% Dairy Ration"

Table 2. All-Milk Price (\$/cwt), 1990-2010				
<i>Year</i>	<i>Minimum</i>	<i>Maximum</i>	<i>Standard deviation</i>	<i>Average</i>
1990	12.50	14.63	0.90	13.68
1991	11.33	13.73	1.08	12.24
1992	12.87	13.47	0.27	13.09
1993	12.30	13.40	0.46	12.80
1994	12.47	13.50	0.42	12.97
1995	12.23	13.77	0.70	12.74
1996	13.93	15.93	0.91	14.88
1997	12.63	14.53	0.89	13.34
1998	13.83	17.93	1.76	15.50
1999	12.83	15.93	1.33	14.36
2000	11.87	12.67	0.41	12.32
2001	13.33	16.60	1.39	14.97
2002	11.33	13.10	0.73	12.11
2003	11.00	14.40	1.61	12.52
2004	14.10	18.53	1.85	16.05
2005	14.77	15.67	0.39	15.13
2006	11.93	13.87	0.94	12.88
2007	15.00	21.67	3.18	19.13
2008	16.80	19.23	1.06	18.33
2009	11.60	15.40	1.73	12.83
2010	15.07	17.70	1.19	16.29

Source: USDA, "All-Milk Price"

Table 3. CWT Retirements Summary Statistics				
<i>Year</i>	<i>Farms Accepted</i>	<i>Cows removed</i>	<i>Milk removed (mil. lbs)</i>	<i>Avg. herd size</i>
2003	299	32,724	609	109
2004	363	50,478	908	139
2005	442	64,069	1,174	145
2006	-	-	-	-
2007	333	52,783	1,001	159
2008	387	75,215	1,408	197
2009	791	200,493	3,988	238
2010	187	31,159	584	167
Totals	2,802	506,921	9,672	181

Source: CWT “Summary of Herd Retirements”

Table 4. CWT Herd Retirements and U.S. Dairy Herd Size (1000 head), 2003-2010			
<i>Year</i>	<i>U.S. Dairy Herd</i>	<i>CWT Retirements</i>	<i>Ratio, CWT to U.S. Herd</i>
2003	9,036.4	32.724	0.36%
2004	9,005.2	50.478	0.56%
2005	9,074.0	64.069	0.71%
2006	9,139.5	-	-
2007	9,219.3	52.783	0.57%
2008	9,315.1	74.715	0.80%
2009	9,148.7	200.761	2.19%
2010	9,117.0	31.159	0.34%

Source: CWT “Herd Retirement Summary”, USDA “Milk Cow Numbers”

Table 5. Variable Descriptions		
<i>Variable</i>	<i>Description</i>	<i>Data source</i>
$COW_{i,t}$	Cow numbers, dependent variable	USDA, “Milk Cow Numbers”
$SPR_t, SUM_t, FALL_t$	Seasonal dummy variables	-
$D_{NE,t}, D_{SE,t}, D_{MW,t}, D_{SW,t}$	Regional dummy variables	-
$COW_{i,t-1}$	Cow numbers, period t-1	USDA, “Milk Cow Numbers”
$CWT_{i,t}$	CWT removals	CWT, “Summary of Herd Retirements”
$AMP_{i,t-1}$	All-Milk price, period t-1	USDA, “All-Milk Price”
$FeedP_{i,t-1}$	Feed price, period t-1	USDA, “16% Dairy Ration”
$CullP_{i,t-1}$	Cull price, period-1	USDA, ERS, “Boning Utility Cows, Sioux Falls,” “Utility Cows, Omaha”
$MILC_{i,t-1}$	Milk Income Loss Contract payments	USDA, “MILC Payments”
* i = region [(Northeastern (NE), Upper Midwest (UM), Southeast (SE), South (S), West (W)]		
** t = quarterly time periods, (1990.1, ...,2010.4)		

Table 6. OLS Estimates of the U.S. Cow Numbers Equation		
<i>Variable</i>	<i>Coefficient Estimate</i>	<i>P-value</i>
Intercept	11.730	0.063
SPR _t	-1.802	0.218
SUM _t	3.733	0.007
FALL _t	1.480	0.296
DNE _t	-26.694	0.000
DSE _t	-37.554	0.000
DMW _t	-17.297	0.000
DSW _t	-22.307	0.000
COW _{i,t-1}	0.989	0.000
CWT _{i,t}	-0.491	0.000
AMP _{i,t-1}	1.936	0.000
FeedP _{i,t-1}	-1.368	0.009
CullP _{i,t-1}	0.123	0.086
MILC _{i,t-1}	2.288	0.046
R ²	0.999	

<i>Quarter</i>	<i>CWT removals</i>	<i>CWT coefficient</i>	<i>CWT net effect on herd size</i>	<i>Avg. yields (1000 lb/cow)</i>	<i>CWT effect on milk production (1000 lbs)</i>
2003.4	32,724	-0.491	-16,067.5	4.36	-70,054.2
2004.4	50,478	-0.491	-24,784.7	4.40	-109,052.7
2005.4	64,069	-0.491	-31,457.9	4.50	-141,560.5
2007.2	52,783	-0.491	-25,916.5	4.85	-125,694.8
2008.3	24,085	-0.491	-11,825.7	4.63	-54,753.2
2008.4	50,630	-0.491	-24,859.3	4.66	-115,844.5
2009.2	101,040	-0.491	-49,610.64	4.96	-246,068.8
2009.3	74,113	-0.491	-36,389.5	4.73	-172,122.3
2009.4	25,608	-0.491	-12,573.5	4.73	-59,472.8
2010.3	31,159	-0.491	-15,299.1	5.27	-80,626.1

Sources: CWT, “Summary of Herd Retirements”, USDA, “Milk Production per Cow”

Table 8. Supply changes and price responses with respective elasticities for milk				
<i>Quarter</i>	$\% \Delta Q$	$\% \Delta P (-0.1 e)$	$\% \Delta P (-0.2 e)$	$\% \Delta P (-0.8 e)$
2003.4	-0.0017	0.018	0.009	0.002
2004.4	-0.0028	0.028	0.014	0.003
2005.4	-0.0035	0.035	0.017	0.004
2007.2	-0.0028	0.028	0.014	0.004
2008.3	-0.0013	0.013	0.006	0.002
2008.4	-0.0027	0.027	0.013	0.003
2009.2	-0.0053	0.054	0.027	0.007
2009.3	-0.0040	0.040	0.020	0.005
2009.4	-0.0014	0.014	0.007	0.002
2010.3	-0.0017	0.017	0.008	0.002

Table 9. CWT Herd Retirement short-run return on All-Milk Price given different price elasticities for milk, (\$/cwt), 2003 to 2010

<i>Quarter</i>	<i>-0.1</i>	<i>-0.2</i>	<i>-0.8</i>
2003.4	0.26	0.13	0.03
2004.4	0.44	0.22	0.06
2005.4	0.52	0.26	0.07
2007.2	0.52	0.26	0.07
2008.3	0.24	0.12	0.03
2008.4	0.45	0.22	0.06
2009.2	0.62	0.31	0.08
2009.3	0.48	0.24	0.06
2009.4	0.21	0.11	0.03
2010.3	0.28	0.14	0.04

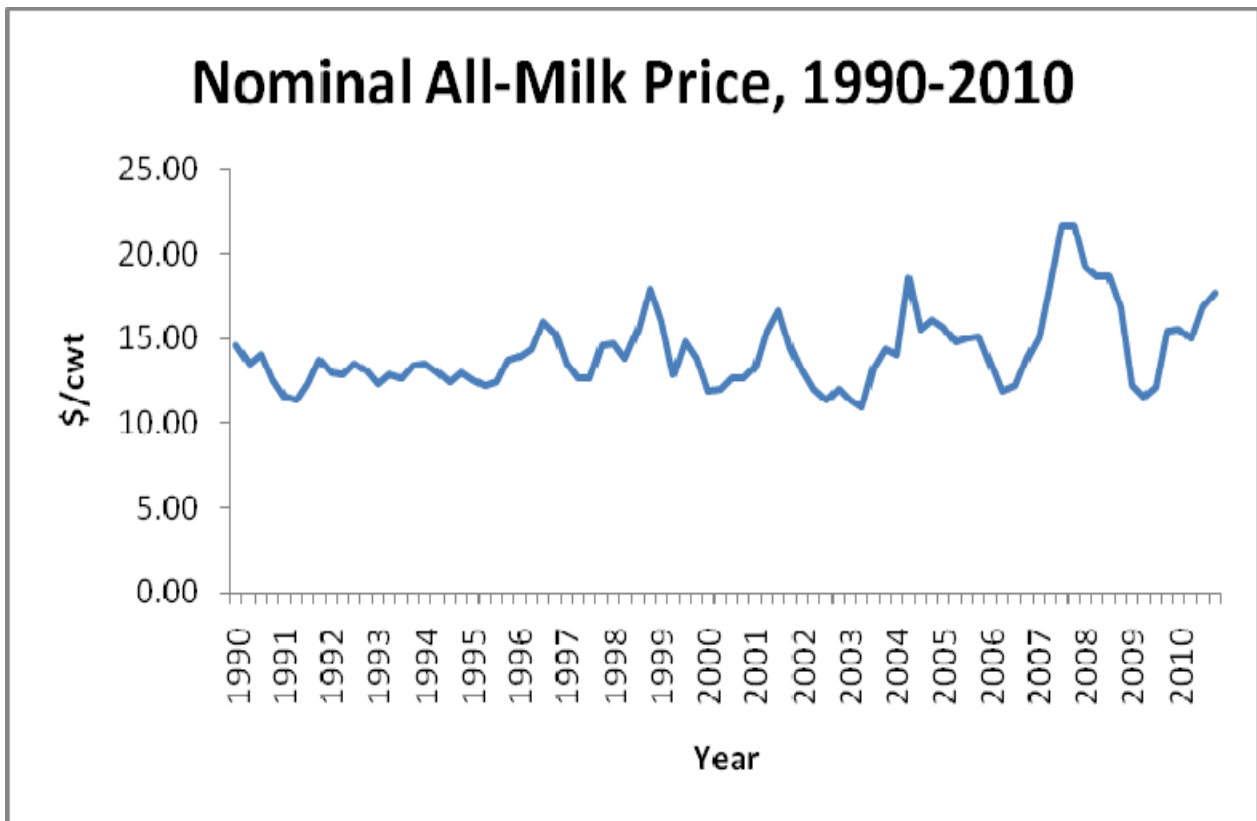
Table 10. CWT Herd Retirement changes in All-Milk price (\$/cwt), 2003 to 2007					
	<i>2003</i>	<i>2004</i>	<i>2005</i>	<i>2006</i>	<i>2007</i>
*Herd Retirement:	0.05	0.17	0.42	0.55	0.62
Removal short-run effect:					
-0.1 e	0.26	0.44	0.52	-	0.52
-0.2 e	0.13	0.22	0.26	-	0.26
-0.8 e	0.03	0.06	0.07	-	0.06

Source: *Brown, "Economic Effect of the CWT Program"

Table 11. U.S. average quarterly milk yields per cow (1000 lbs), 1990-2010				
<i>Year</i>	<i>Minimum</i>	<i>Maximum</i>	<i>Standard deviation</i>	<i>Average</i>
1990	3.55	3.75	0.09	3.62
1991	3.60	3.81	0.09	3.68
1992	3.72	3.89	0.08	3.79
1993	3.74	3.97	0.11	3.82
1994	3.81	4.03	0.09	3.89
1995	3.83	4.09	0.12	3.94
1996	3.83	4.06	0.10	3.96
1997	3.94	4.18	0.12	4.04
1998	3.98	4.25	0.12	4.10
1999	4.05	4.33	0.12	4.20
2000	4.16	4.43	0.15	4.30
2001	4.19	4.47	0.12	4.31
2002	4.30	4.60	0.15	4.43
2003	4.30	4.59	0.13	4.44
2004	4.38	4.64	0.13	4.50
2005	4.50	4.80	0.13	4.61
2006	4.54	4.85	0.15	4.67
2007	4.61	4.85	0.11	4.70
2008	4.63	4.90	0.13	4.75
2009	4.73	4.96	0.11	4.82
2010	5.21	5.46	0.12	5.29

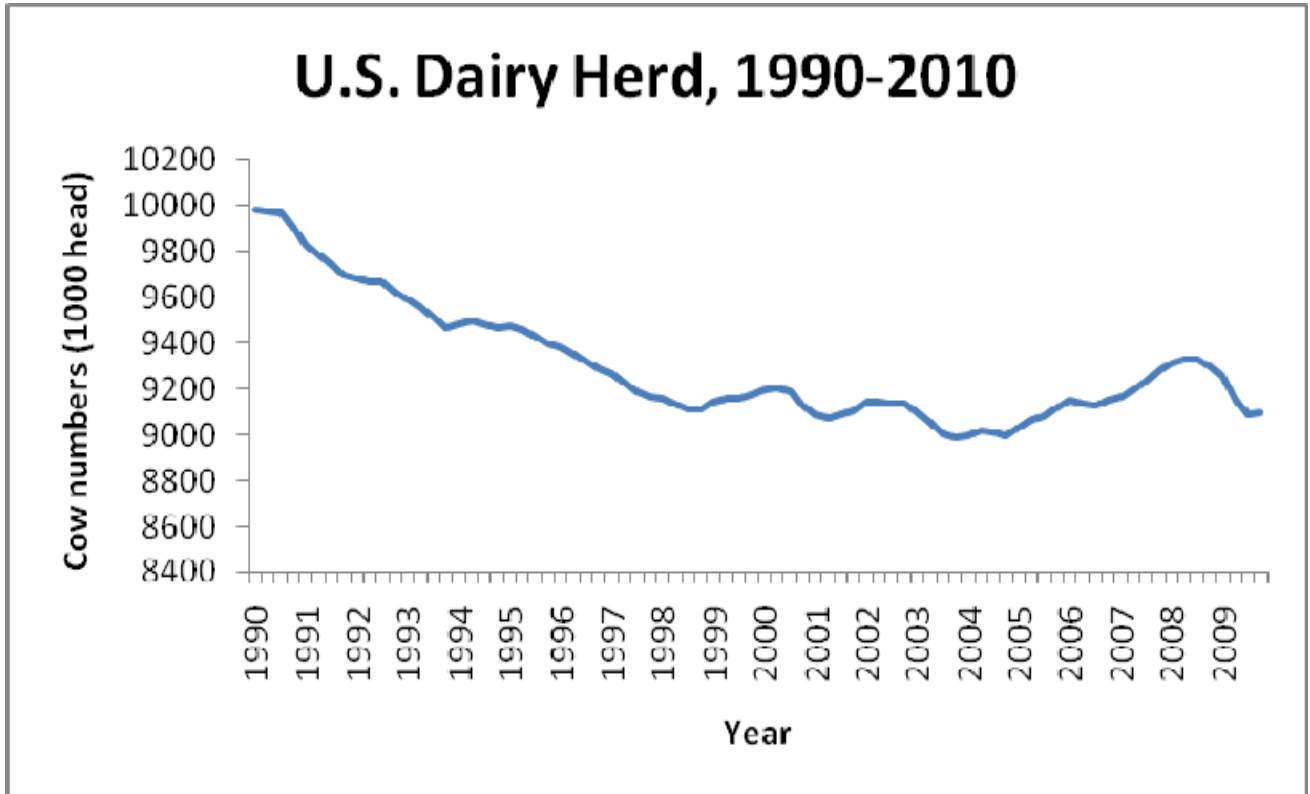
Source: USDA, "Milk Production per Cow"

Figure 1.



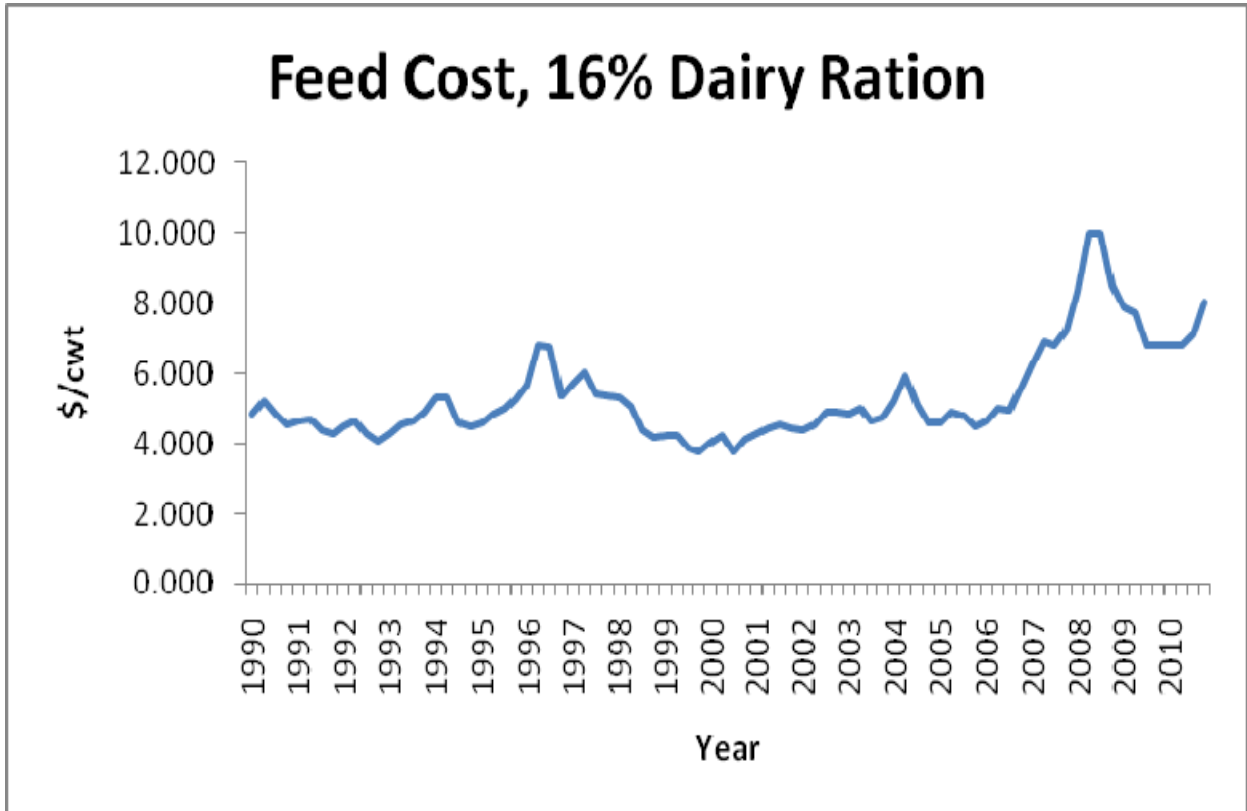
Source: USDA "All Milk Price"

Figure 2.



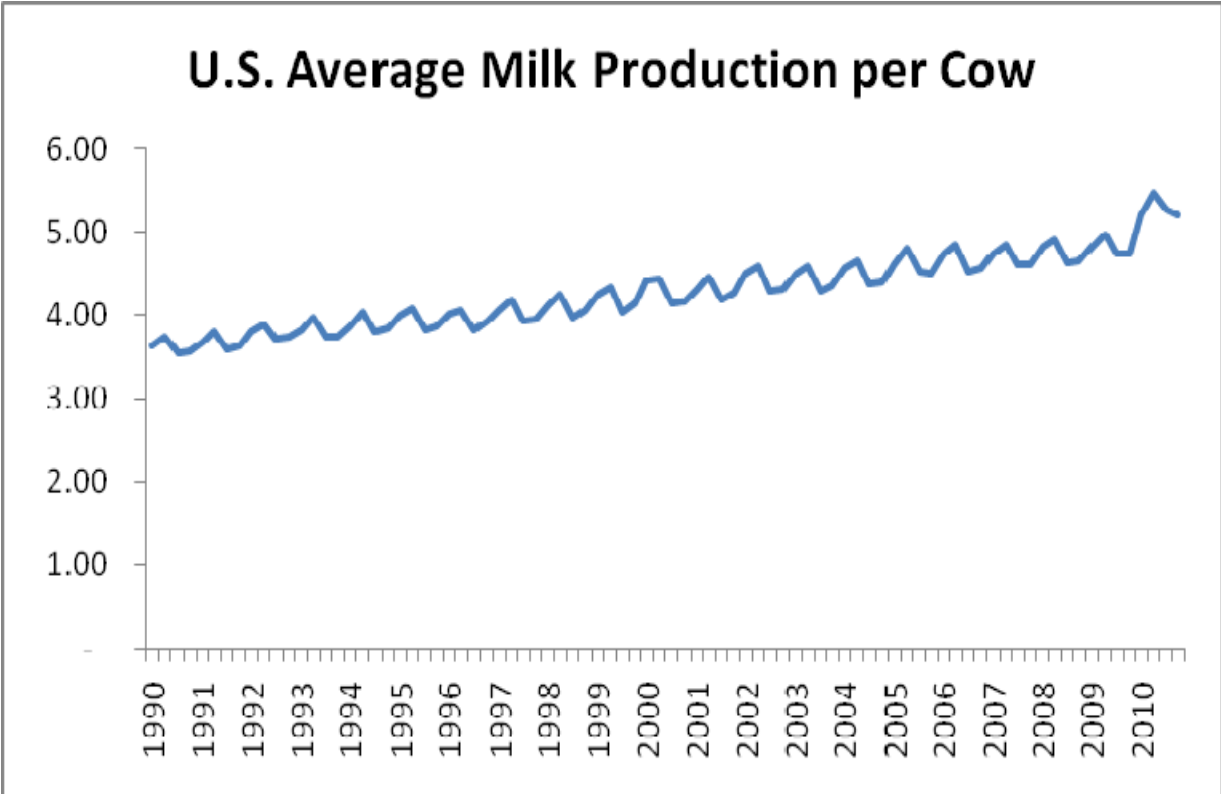
Source: USDA "Milk Cow Numbers"

Figure 3.



Source: USDA "16% Dairy Ration"

Figure 4.



Source: USDA, "Milk Production per Cow"