Milk Futures Contracts and Maturity Effect
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Executive Summary

Understanding the nature of the price risk is essential for milk marketing plans. There are several tools available in the market place to take care of price risks such as futures contracts, options and forward contracts. Large price changes or volatility is present in both the milk cash and futures prices. No systematic statistical studies of volatility are available for milk futures contracts because of recent introduction of the futures contracts in milk.

This study is aimed at understanding the nature of volatile milk futures prices as well as the associated price risk factors or determinants of price risk. In particular, this study examined the effect of maturity on milk Class III futures daily price returns volatility using OLS regressions in a multivariate setting. The maturity effect refers to increasing volatility of futures prices as the contract approaches expiration. Maturity effect has important implications on the behavior of futures prices.

The results support that there is no maturity effect in the milk futures contracts studied. In fact, opposite to maturity effect, the variance of daily milk futures price returns decreased as the maturity time approached. Among the other determinants of volatility, the year effect is pronounced in milk futures price daily returns and significant contract-month and calendar-month effects were observed. After controlling for contract-month and calendar-month effects milk futures prices showed declining variance in daily returns.

Introduction

Milk price fluctuations have caused several business failures in the dairy industry leading to major changes in the industry structure. Government policy changes have led dairy producers to be more market oriented. Milk producers are facing several market risks of which, price risk is the most important. Understanding the nature of the price behavior is essential for milk marketing plans. There are several tools available in the market place to take care of price risks such as futures contracts, options and forward contracts.

Large price changes or volatility is present in both the milk cash and futures markets. Even though, low milk prices are thought to be the major reasons that lead to the depressed income for a majority of the dairy producers, the most important factor is the variation in the prices and incomes from year to year that are causing lots of stress in the dairying business.

Because of the same fundamental demand and supply that influence cash and futures prices, there is much variability in the futures prices of milk as that of cash prices. The price variability of futures contracts has attracted a great deal of attention and been explored in several agricultural commodities except milk. No systematic statistical studies of volatility are available for milk futures contracts because of recent introduction of the futures contracts in milk.
Currently, milk producers and processors are facing increased price risk in milk Class III futures. This study’s aim is at understanding the nature of volatile milk futures prices as well as the associated price risk factors or determinants of price risk. In particular, this study examines the effect of maturity on milk Class III futures prices volatility. The maturity effect refers to increasing volatility of futures prices as the contract approaches expiration. Maturity effect has important implications on the behavior of futures prices.

We test whether there is an inverse relationship between time to maturity of the milk contracts and the daily returns variability using multiple-regression analysis methods. In a multivariate setting, the maturity effect is tested by performing the statistical significance tests on the coefficient estimates of the regressions for all milk contracts studied.

The article is organized as follows. First a brief explanation of milk pricing system is presented to understand this report better. Section 2 and 3 provides literature review along with the objectives and hypothesis to be tested. In sections 4 and 5 the data and methodology, giving the statistical models and the testing of the maturity effect hypothesis was presented. In the last two sections, 6 and 7, results, summary and discussion was provided.

1. Current Milk Pricing System

In milk pricing, current month cash prices are announced by the government agency, United States Department of Agriculture (USDA), that is arrived at by using a complex formula. Each month, cash prices that producers will receive for that month will be announced in the first week of next month. For example, a producer will know the cash prices he/she will receive for the milk produced in the month of March during the first week of April. These cash prices are popularly called as ‘mail box prices’ as the producers receive the milk check using the cash prices that are determined based on a formula pricing method. So for any given month the cash price is the same but it could vary substantially from month to month.

Throughout the 1970s and 1980s milk prices tended to be stable. Government support prices have helped to keep the price of milk stable and the dairy industry less risky. As the support prices started dropping following the farm bill of 1996 (FAIR act) the risk levels elevated and the market forces were set free. The changing structure of the industry and the decrease in governmental support are making the producers to confront more market risks than ever and to become more market oriented.

There are many tools available to lay off risk and protect profitability, such as futures market, forward contracts, and options. These tools can be used in the hedging operations to manage the price risk. The Chicago Mercantile Exchange (CME) introduced milk futures contracts in 1997 after the government lifted price control in the dairy industry. The use of the milk futures contracts has exploded since its inception at the CME as indicated by the volume of trade. There are different classes of milk but most importantly traded contracts are of the Class III milk (fluid milk).
To encourage the use of these price risk management tools (futures and options), USDA has introduced Dairy Options Pilot Program (DOPP) in 1999 to subsidize dairy farmers who purchase milk put options. Since then the commercial hedging activity has peaked in milk futures and options contracts due to market incentives given by the government.

Because of the same fundamental demand and supply that influence cash and futures prices, there is much variability in the futures prices of milk as that of cash prices. From 2000 to 2002 alone, the class III annual average had price swings of -22%, +35% and – 20%. Individual contract-months can provide even more of a roller-coaster ride. From 2000 to 2001, the June Class III contract jumped 59%, only to plummet 33% from 2001 to 2002. All this is telling that the futures price volatility is much greater. No research work was done so far to systematically study the factors that determine the volatility in milk futures price. It is an empirical necessity to test for the volatility determinants in the milk futures markets.

2. Literature Review

The price variability of futures contracts has attracted a great deal of attention and has been explored in several agricultural commodities. Many researchers have studied the relationship between maturity and the volatility of futures prices over the life of a large number of agricultural and financial contracts. There is strong empirical support for the maturity effect in futures prices.

Serletis (1992) found support for the maturity effects hypothesis in energy futures. Fama and French (1988) along with the earlier evidence by Anderson (1985) and Milonas (1986) suggest that the maturity effect exists in commodity prices. Milonas (1986) examined eleven commodities (5 agricultural, 3 financial, and 3 metals) and results support the maturity effects hypothesis in 10 out of 11 futures markets. Castelino and Francis (1982) tested maturity effects hypothesis in several major agricultural commodities such as wheat, corn, soybeans, soybean meal, and soybean oil contracts. His research results show the evidence of maturity effect in these commodities. Dusak-Miller (1979) reported support for maturity hypothesis for live cattle futures. Barnhill, Jordan, and Seale (1987) found evidence of a maturity effect in the Treasury-bond futures markets during the period 1977-1984, and Khoury and Yourougou (1993) found support for a maturity effect in their analysis of six Canadian agricultural commodities.

Milonas (1986) studied eleven commodities and found strong support for the maturity effect after controlling for the year effect, the calendar-month (seasonality) effect, and the contract-month effect. Anderson (1985) studied nine commodities and found support for the maturity effect, but concluded it is secondary to the effect of seasonality.

Most recently, Galloway and Kolb (1996) studied maturity effect approximately in 45 different commodities over the years from 1969 to 1992, and employed an alternative methodology to control for the effect of the year, calendar-month, and contract-month. They found strong support for the maturity effect in agricultural and energy commodities but not in precious metal and financial instruments. This study concluded that the maturity effect is an important source of volatility in futures prices for commodities that experience seasonal demand.
or supply, but not for commodities for which the cost-of-carry model works well.

Given the significant research work done in several agricultural commodities on maturity effect, milk futures prices are not studied well as the milk futures contracts are most recent introductions to the market. As the rate of increase in the futures and options volume is exploding in milk contracts the need to study the behavior of prices has significant impacts on milk marketing plans of producers, assemblers, processors, and several milk marketing cooperatives.

One significant factor that affects the futures price variability is the changing time to maturity. Samuelson (1965) was the first to theoretically advance the maturity-effect hypothesis, which states that the variability of prices increases monotonically as the contract approaches maturity. As mentioned earlier, several studies provided evidence that time to maturity is an important determinant of the behavior of variability of futures prices. The maturity effect refers to the idea that futures contracts near to maturity exhibit greater volatility (fluctuations in price) than futures contracts away from maturity.

3. Objective(s) & Hypothesis

We examine several factors that cause milk futures price volatility but focus specific attention on the maturity effect in milk Class III futures price as this effect is found to exist in the futures prices of most commodities.

We also looked into other known factor such as seasonality or calendar-month effect, year effect, and contract-month effect. Random shocks affecting the demand or supply in the product markets affect differently the year-to-year variability of spot and futures prices. This non-stationarity factor is known as year effect. Similar shocks within a year due to seasonality, mainly the supply, are captured in the form of different monthly price variability and it is known as month-effect. The random shocks associated with the fact that futures contracts mature in different calendar months are captured in the price variability specific to the contract maturity month and is known as the contract-month effect.

Hypothesis:

We test the Samuelson (1965) hypothesis or maturity effects hypothesis, which states that the volatility of futures price changes per unit of time increases as the time to maturity decreases. The null hypothesis is constructed as follows:

**Null Hypothesis: H(0):** There is no relationship between time to maturity and futures price variability in milk futures.

**Alternate Hypothesis: H(1):** There is an inverse relationship between time to maturity and variability of futures price changes in milk futures.
4. Data Sources

The data in this study consisted of daily settlement prices for milk Class III futures contracts from 2000 to the most recent time period. Milk Class III contracts are being traded for all twelve months of the year.

The data period covered in this analysis is from 2000-2005 contracts. Milk futures started trading from 1997 onwards and received low volume in the initial two years. After the introduction of DOP (Dairy Options Pilot) program in 2000 the volume had picked up in milk futures trading. The data is collected from the Wisconsin Cooperative Extension web site, Understanding the Dairy Markets (2005).

Futures settle prices of the last six months close to expiration of the futures contract month were collected. This includes the month the milk futures contract expires. Analysis is limited to the six months close to expiration because, the open interest is low and trading volume is thin in periods long before maturity. We included the expiration month as one of the last in the six months because the milk futures contracts will trade during the designated expiration month and will expire in the first week of the following month. And these contracts are cash settled rather than calling for actual delivery of the milk.

There are a total of 23745 observations of daily settle prices in the data set. This data comes from 55 milk contracts with expiration in all the calendar months of the year. For the calendar-months of January to July, each month had 5 contracts and from August to December, each month had 4 contracts in the data set.

5. Methodology

Anderson (1985), using various statistical techniques, provided support for the maturity effect, but recognized seasonal patterns in futures prices as more important determinants of the volatility. In Anderson’s methods there is no consideration of the contract-month effect. As noted by Milonas (1986), if variability of futures prices is affected by the month of maturity, non-adjustment for the contract-month effect might introduce serious bias, especially for agricultural commodities. He also noted few constraints to Anderson’s methodology.

We followed the most recent methodological approaches taken by Galloway and Kolb (1996) that were much more improved than any other studies that we reviewed. For each futures contract daily settlement prices were used to calculate daily futures returns. Monthly variances of these returns for each of the six months including the expiration month of the contract were computed. Following most prior studies, the return for futures contract \( j \) on day \( t \) in the \( k_{th} \) month before expiration, \( F_{j,k,t} \), is calculated as the proportional change in the settlement price from day \( t-1 \) to day \( t \);

\[
F_{j,k,t} = \left( \frac{S_{j,k,t}}{S_{j,k,t-1}} \right) - 1
\]  

(1)

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Where $S_{j,k,t}$ is the settlement price for futures contract $j$ on day $t$ in month $k$ ($k = 1$ to $6$).

The volatility of the daily returns for contract, $j$, in month $k$, $\sigma_{j,k}^2$ is calculated using the statistical estimator of variance:

$$\sigma_{j,k}^2 = \frac{\sum_{t=1}^{n_{j,k}} \left( F_{j,k,t} - \overline{F}_{j,k,t-1} \right)^2}{n_{j,k}}$$  \hspace{1cm} (2)

In a multivariate setting, the maturity effect is investigated by performing the following ordinary least squares (OLS) regression for all contracts available.

$$\sigma_{j,k}^2 = \alpha + \beta k + \gamma \sigma_{j,6-month}^2 + \epsilon$$ \hspace{1cm} (3)

Where $\sigma_{j,k}^2$ is the volatility of the returns for futures contract $j$ in the $k_{th}$ month before expiration of the contract, $k$ is the time (in months) remaining for contract $j$ to mature and $\sigma_{j,6-month}^2$ is the variance of futures returns for contract $j$ over the entire six-month period.

By extending the above equation to control for the year effect, contract-month effect, and calendar-month effect the following multiple regression was estimated.

$$\sigma_{j,k}^2 = \alpha + \beta k + \gamma \sigma_{j,6-month}^2 + \sum_{i} \delta_i C_{j,k,i} + \sum_{m=1}^{11} \theta_m M_{j,k,m} + \epsilon$$ \hspace{1cm} (4)

We test for the maturity effect, year, seasonality or calendar-month and contract-month effect by testing the appropriate coefficients using the t-test and F-ratio tests. We test the null hypothesis of no maturity effect, ($\beta = 0$), and the null hypothesis of no year effect ($\gamma = 0$) by conventional t-statistic tests. Placing linear restrictions on the model in the above equation creates joint and individual tests of the contract-month effect and the calendar month effect. To test for contract-month and calendar-month effects jointly an F-statistic that is computed from full model and restricted model was tested.

6. Results

Using the settlement prices for all the contracts daily price returns were calculated as shown in the equation 1. Next, the monthly variances of daily returns of futures settle price were calculated for each contract using the equation 2. This yielded a total of 330 variance observations for all the 55 contracts analyzed in this study.

Table 1 represents the results of the OLS regression in equation 3 for all contract months of milk futures. The table reports the coefficient estimates, associated t-values, probability, adjusted $R^2$, other statistics and diagnostics.
Table 1: OLS Regression results

Regression Model: \( \sigma_{j,k}^2 = \alpha + \beta k + \gamma \sigma_{j,6-month}^2 + \varepsilon \)

Dependent Variable: RETURNSVARIANCE
Method: Least Squares
Model
\( \sigma_{j,k}^2 = \alpha + \beta k + \gamma \sigma_{j,6-month}^2 + \varepsilon \)

Included observations: 330

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<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
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R-squared       0.233710   Mean dependent var  0.000133
Adjusted R-squared 0.229023  S.D. dependent var  0.000218
S.E. of regression 0.000192   Akaike info criterion -14.27190
Sum squared resid 1.20E-05   Schwarz criterion -14.23736
Log likelihood 2357.863     F-statistic  49.86573
Durbin-Watson stat 2.158831  Prob(F-statistic)  0.000000

In table 1, the t-statistic for the test of the null hypothesis of no year effect, \( \gamma = 0 \), indicate that the null hypothesis is rejected. The estimate of year effect coefficient is positive and significant which means that the monthly variance of futures returns increases as the variance in the six months before expiration increases, holding all else constant. This result support a year effect in which general conditions can affect supply or demand over an extended period.

From the same table the test of the null hypothesis of no maturity effect, \( \beta = 0 \), indicate that the null hypothesis is not rejected with a p-value of 0.1326. The sign of \( \beta \) is positive, that is, the monthly variance of futures returns decreases as the time to maturity decreases, holding all else constant. But this coefficient is insignificantly different from zero. This result supports that there is no maturity effect in milk futures contracts studied.

The \( R^2 \) value, 23.37% tells the amount of variation in daily milk futures price returns has been explained by the year and maturity variables. The residual analysis of regression residuals indicate that the assumptions of OLS regression hold well. The Durbin-Watson statistic of 2.16 tells that there are no serial correlations in these residuals.

Table 2 represents the results of the OLS regression in equation 4 for all contract months of milk futures. In this extended equation, dummy variables to account for calendar-month or seasonal (Month variables 1-11) and contract-month (Cont variables 1-11) effects were introduced. The table 2 reports the coefficient estimates, associated t-values, probability, adjusted \( R^2 \) etc.,
Table 2: OLS Regression results

Regression Model: \[ \sigma^2_{j,k} = \alpha + \beta k + \gamma \sigma^2_{j,6-month} + \sum_{i} \delta_i C_{j,k,i} + \sum_{m=1}^{11} \theta_m M_{j,k,m} + \epsilon \]

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<tr>
<th>Variable</th>
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R-squared: 0.358926, Mean dependent var: 0.000133
Adjusted R-squared: 0.310741, S.D. dependent var: 0.000218
S.E. of regression: 0.000181, Akaike info criterion: -14.32304
Sum squared resid: 1.01E-05, Schwarz criterion: -14.04674
Log likelihood: 2387.302, Durbin-Watson stat: 2.139937

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From table 2, after controlling for the seasonal or calendar-month and contract-month effects, the coefficient estimate of the maturity effect is significant at 0.10 significance level (p-value = 0.06). At a 0.05 significance level the coefficient estimate is not different from zero. The associated sign is positive, which indicates that the variance of daily milk futures price returns decrease as the maturity time approaches. This is opposite to what was found in other agricultural commodities studies where maturity effect was identified.

The year effect is pronounced in milk futures price daily returns with a very high t-value for the year effect coefficient. The contract-month effect for the months of May and June is significant with high t-values and with a p-value below 0.05. This indicates that the milk futures contract months of May and June have significant daily returns variance when compared to all other months. Calendar-month or seasonality tests using the seasonal dummy variables reveal that the June, July, August and Sept are significant with p-values less than 0.05 and May month with a p-value below 0.10. During these months seasonally the futures price daily returns vary significantly.

The $R^2$ value, 35.89% tells the amount of variation in daily milk futures price returns has been explained by maturity effect, year, contract-month and calendar-month variables. The residual analysis of regression residuals indicate that the assumptions of OLS regression hold well. The Durbin-Watson statistic of 2.13, tells that there is no serial correlation in these residuals.

Joint hypothesis tests were conducted to check for the presence of contract-month and calendar-month effects. The F-statistics and p-values for the test of the null hypothesis of no contract-month effect, $\delta_i = 0$ for all i, had a F-statistic of 5.42 with p-value of 0.00. This indicates that the null hypothesis is rejected and there is evidence of contract-month effect in daily returns of milk futures prices. Similar to the results for contract-month, the null hypothesis of no calendar-month effect, $\theta_m = 0$ for all m, had a F-statistic of 2.19 with p-value of 0.04. This indicates that the null hypothesis is rejected and there is evidence of calendar-month or seasonality in the variance of daily returns of milk futures prices.

Another, joint null hypothesis, that there is no calendar-month and contract-month effect, i.e. $\delta_i = 0$ for all i and $\theta_m = 0$ for all m, was rejected with a F-statistic of 2.74 with a p-value of 0.000065. These results show that there are both the calendar-month and contract-month effects in the daily returns variance of milk futures prices.

7. Summary and Conclusions

Even though it appears the maturity effect plays a significant role in the volatility of futures prices for the commodities that experience seasonal demand or supply, milk futures prices do not show any maturity effect. In a multivariate setting after controlling for other factors of volatility such as year effect, calendar-month effect and contract-month effect there was some evidence of reduced variance in the milk futures daily returns as the maturity neared for the contracts. This finding is opposite to what maturity effect hypothesis states. The seasonality or
calendar-month, contract-month and year effect were more pronounced in milk futures price daily returns variance.

Both the nature of the commodity and the method of settlement are different in milk contract compared to some storable agricultural commodities. Milk is a non-storable and highly perishable commodity. The contract settlement in through non-delivery i.e. by cash settlement to the announced prices. Milk futures prices showed decline in the variance as the contracts came to maturity and similar kinds of results were observed in earlier studies for some non-storable commodities. There was no maturity effect in milk futures contracts. As the contracts neared maturity the variance decreased after controlling for other determinants of price volatility.

Milk had high degree of seasonality in both production and prices. Even though milk will be produced throughout the year there are strong seasonal patterns in the milk production that results in price variability. There is strong seasonal evidence, and the months in summer and early fall months had significant variance in daily futures returns. This result validates other studies about milk price seasonality. June, July, August and September months have shown significant seasonal variation in milk daily futures returns. Taking these seasonal tendencies in milk futures prices and increased seasonal variability, the hedgers should make their hedging decisions.

The contract-months that mature in the summer months of May and June had significant daily futures returns variance. These were also the months where we found strong seasonal variation. This result shows that it is better to hedge whenever an opportunity arises prior to these months the anticipated production that arrives in these months i.e. lock-in to a better price to manage price risk in these months well in advance using distant months rather than contacts close to expiration in hedging operations.

The findings of this research will help the dairy businesses to evaluate their current milk marketing strategies, in refining the marketing plans by better understanding the nature of price variability by identifying the significant factors that influence price behavior, such as strong seasonal, calendar-month and year effects but no maturity effect.

Milk Class III futures contract represents milk used mainly in the manufacturing of cheddar cheese. All factors affecting milk production and cheese cash prices influence the price direction of this contract. To better understand the nature of milk price behavior further studies of cheese and milk prices in a multivariate, co-integrated frame work are needed.

Along with milk futures the CME introduced several other dairy products futures contracts in butter, cheese and non-fat dry milk, popularly referred to as ‘dairy complex’. Similar kind of analysis should be extended to these commodities in order understand about the price risk factors in the dairy complex contracts.
Bibliography

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13) WMMB web address: http://producer.wisdairy.com/