Milk Price Volatility and its Determinants

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Abstract: The classified pricing of fluid milk under the Federal Milk Marketing Orders (FMMO) system combined with the cash settlement feature of Class IIII milk futures contracts generate a unique volatility pattern of these futures markets in the sense that the volatility gradually decreases as the USDA price announcement dates approaching in the month. Focusing on the evolution of volatility in Class III milk futures market, this study quantifies the relative importance of a set of factors driving milk price variation. While volatilities in both corn futures market and financial market Granger-cause the milk price volatility, the impact of financial market is more persistent. Besides embedded seasonality, market demand and supply conditions in the dairy market, cheese in this case, as well as changes in the U.S. exchange rates are found to have positive and statistically significant impacts on milk price volatility. While speculation positively affects milk futures markets, the effect was found insignificant.

Keywords: Cash settlement, impulse responses, milk pricing, realized volatility, speculation.

JEL Classification: Q11; Q14.

Introduction

In the past 20 years, the dairy industry has suffered severe price fluctuations with a general pattern of increased volatility (see figure 1). In May 2004, the Class III milk price increased to $20.58/cwt and then decreased to $10.83/cwt in May 2006. In July 2007, the Class III price reached a record $21.38/cwt and then collapsed to $9.31/cwt in February 2009. High price volatility within the dairy industry has caused hardship for dairy farmers as dairy farms tend to be less diversified and more reliant on returns from their farm business than other farms (USDA, 2004). It also adds difficulties to dairy farms in both business and financial planning and directly increases the market risk.

The inherent characteristics of milk and its products make dairy markets vulnerable to price volatility, such as bulkiness, extreme perishability, and inelastic demand. Seasonal price variation induced by mismatched production and demand, i.e., peak milk production in the spring versus high demand for dairy products in the late fall, also leads to large monthly price changes. Other factors, such as changes in policy or regulatory issues (i.e., Dairy Product Support Program, DPSP, and Federal Milk Marketing Orders, FMMO) and increasing exposure to international markets are also indicated in a number of ad hoc studies as contributing factors.

The federal government plays a prominent role in the process of establishing the farm value of milk via the DPSP and FMMO's (Shields 2009). The price support program maintains a floor for dairy product prices through government purchases of butter, cheddar cheese, and nonfat dry milk at legislated prices. It provided a safety net for dairy farmers especially prior to 1990s. Some studies (Chavas and Kim, 2004; Chavas and Kim, 2006; Kim and Chavas, 2002) find that price support program had been effective in reducing price volatility during the period when supporting prices were binding most of time. The effect of the federal price support program on milk prices, however, has been substantially reduced since 1990. Although there are significant increases in production cost, especially in feed and fuel costs, the DPSP is set at levels much below farmers' production cost[1] (Jesse and Cropp, 2010) and thus does not provide enough protection to farmers.

The FMMO, established in 1937, sets up monthly minimum prices paid by regulated processor/manufacturers for classified milk by its end use. The minimum price producers receive is a blend of minimum prices of all uses. The FMMO pricing formulas were changed to end product pricing in 2000, where class milk prices are derived from wholesale prices of end dairy products.[2] Such direct linkage to commercial markets for the dairy products, which are typically quite volatile, has been alleged to be one of the important factors causing the increased increasing milk price volatility since 2000 (USDA, 2011).

Recent U.S. dairy policy reform and trade liberalization have enhanced the access to foreign markets for the U.S. dairy sector. A growing and significant proportion of U.S. milk supply has been sold in the international markets. For example, U.S. dairy exports in 2010 increased 39% over the 2009 level to 1.5 million tons, representing 13% of total milk solids sold (USDEC 2011). Growing trade makes U.S. milk prices increasingly influenced by changes of supply and demand conditions in the international dairy markets, which are considerably affected by factors that randomly happen, such as adverse weather and trade policy changes.

Another significant event that has changed dairy markets is the emerging ethanol market and record high corn and soybean prices. Corn-based ethanol has become an increasingly

[1] The milk support price was set at $9.9/cwt by the 2002 Farm Bill. Although the 2008 Farm Bill did not specify milk support price, through end products pricing formulas, support prices for butter, cheese, and nonfat dry milk continue to generate a $9.90/cwt milk support price (Jesse and Cropp, 2008).
[2] Readers referred to Jesse and Crop (2010) for more details.

important component of the U.S. transportation fuel supply. U.S. ethanol production increased from 3.9 billion gallons in 2005 to 13.2 billion gallons in 2010 (RFA 2011). By the end of 2010, ethanol was blended into over 90% of the U.S. gasoline (RFA 2011). The share of corn used for ethanol production increased from 5% in the mid-1990s to over 40% in the 2010/11 crop year (FAPRI 2011). The U.S. corn prices increased to an all-time high of over $7 per bushel in spring 2011 amid tight supply and strong demand driven in part by rapid expansion of biofuels production. As the major component of feed cost, high corn price leads to record high feed cost and consequently pushes up milk prices. In the meantime, variation in corn price should have transmitted to milk price.

Analysis of milk price volatility and its determinants has been largely neglected in the literature. Although there are a number of studies qualitatively describe milk price volatility and contributing factors (e.g., USDA, 2011; EDA, 2009), rigorous empirical studies are missing. Chavas and Kim (2004) conduct an econometric analysis of the effects of price floors on price volatility in US dairy markets. Using a dynamic tobit model and focusing on price support program, they find that price support program has been effective in reducing price volatility during the period when supporting prices were binding most of time. Similar studies are conducted in U.S. non-fat dry milk (Kim and Chavas 2002), cheese (Chavas and Kim, 2005), and butter markets (Chavas and Kim 2006). As dairy price support program has not been providing sufficient support to farmers especially in recent years, it is crucial to investigate what factors affecting milk price volatility.

This study proposes to fill the gap by analyzing thoroughly the unique characteristics of milk price volatility and quantifying the importance of various factors driving this volatility. Our contributions are three-fold. First, we quantitatively show that the Class III milk pricing scheme and cash settlement feature of the Class III milk futures contracts generate unique patterns of price volatility, which decreases gradually as the USDA price announcement dates approaching. We illustrate the pattern using the recently developed realized volatility measure and high frequency intraday futures trading data. Second, within the framework of nonstructural vector autoregressive model, we conduct Granger causality tests and impulse response analysis on volatility in corn price, financial markets, and milk price. The results indicate that while volatilities in both corn market and equity market Granger-cause the milk price variation, the impact of shocks in financial market is more persistent. Our third contribution is that we identify the determining factors of milk price volatility and quantify their impacts. The supply/demand condition in storable dairy product markets, cheese for Class III milk in this case, and changes in the U.S. exchange rate exert positive and statistically significant effects on the price variability of milk.

The paper proceeds as follows. The current FMMO milk pricing system and its implication on futures price volatility are explained in the next section. Section 3 provides a summary of the nonstructural vector autoregressive model to quantify impacts of corn price and general financial market volatility on Class III milk price variability. Sector 4 investigates various determining factors of Class III milk price volatility and quantifies their effects. Then conclusions and discussions are presented in the final section.

Milk pricing and its implication on volatility

We focus on price and volatility of the Class III milk futures contract in this study. Futures markets for milk are well established and are being widely used by individual farmers, dairy manufacturers and users of dairy products for risk management. Class III milk refers to milk used to manufacture cream cheese and hard cheese.[3] Therefore factors influencing cheese cash prices also affect the price of Class III milk futures contract. Milk Class III futures contracts trade on the Chicago Mercantile Exchange and have historically been the most actively traded dairy futures contract. They are traded in every month of the year, up to 24 months in advance, and end on the business day preceding the one on which the USDA announces the Class III price for that contract month which occurs on a Friday no later than the 5th of the month following production. After expiration, instead of actual physical delivery, futures prices are cash settled to the corresponding Announced Class III price. Minimum Class III prices are formula based and is impacted by the wholesale prices of Butter, cheese, and dried whey, which are determined in competitive markets. The announced price is calculated using a publicly known formula based on weekly National Agricultural Statistics Service (NASS) survey of cheddar cheese, butter, and dry whey prices.[4] Weighted average of the reported weekly product prices that are available on the announcement day are used for the calculation of Class III milk price. For example, the minimum FMMO March 2011class III price was announced on Apr. 1, 2011 and based on NASS survey prices corresponding to the weeks of March 5, 12, 19, and 26.

The milk pricing scheme described above and cash settlement arrangement in the Class III milk futures contract have significant implications for futures price volatility. As price information of the component dairy products is obtained over the production month, price volatility of current maturity contract decreases over time. In the following we illustrate the point using daily realized volatility of high-frequency intraday futures returns.

[3] Four classes of milk is used in federal marketing orders: Class I is milk used for beverage products; class II is milk used for soft manufactured products such as cottage cheese, yogurt, ice cream; class IV is milk used for butter and dry milk products.
[4] Readers are referred to Jesse and Cropp (2008) for more details.

Realized volatility was first proposed by Andersen et al. (2003) with significant advantages over traditional conditional heteroskedasticity model and stochastic volatility model as it effectively exploits the information in intraday return data, and achieves an easy implementation. Following Andersen et al. (2003), We construct the realized volatility to measure milk price return variability on day t as

$$(1)\quad \begin{aligned} RV_t &= \sum_{j=1}^{m} r_{t-1+j\Delta}^2,\ t=1,...,T. \\ r_{t-1+j\Delta} &= p_{t-1+j\Delta} - p_{t-1+(j-1)\Delta},\ j=1,...,m. \end{aligned}$$

where p_t denotes log-price of milk futures at time t, and $r_{t-1+j\Delta}$ represents the intra-day continuously compounded return from time $t-1+(j-1)\Delta$ to $t-1+j\Delta$, and it is obtained by the first difference of the logarithmic prices. The symbol m denotes the number of sampled observations per trading session, and Δ is the fraction of a trading session associated with implied sampling frequency.

We calculate the daily realized volatility of March 2011 (Monday-Friday).[5] The average number of daily transactions is about 22 and varies substantially through the month, from 37 in the first week to 12 in the last week. The estimated realized volatility of the March 2011 Class III futures contract is presented in the upper panel of Figure 2 with dash lines representing polynomial trend line. It shows clearly a significant declining trend for futures price volatility. It illustrates that as USDA announce date is approaching and component prices of dairy product become known, the price gets closer to settlement price, exhibiting less variation in the later of

[5] We use the price data of futures contracts traded on the CME Globex electrionic trading platform, which opens virtually 24 hours a day (5pm central time-4pm central time), mainly because the futures contracts are not heavily traded in the open outcry market with a very limited number of trades on the daily basis.

the month. This declining volatility pattern is generated from two factors: milk pricing scheme and cash settlement of milk futures contracts. In contrast, March contracts are traded much heavier in February with on average double daily trading volumes. The volatility of futures prices in February for March contract exhibits a quite different pattern, which is illustrated in the lower panel, that the volatility doesn't trend down over the month. Considering this unique volatility feature, we define our monthly volatility measurement based only on futures price for the first twenty days in each month as the rest of data contains very limited information on price volatility. Specifically, we define the volatility of milk futures prices using the variance of daily changes of the logarithms of prices in a month. Prices of nearest futures contracts of class III milk traded in Chicago Mercantile Exchange (CME) are used. The generated milk price volatility measures over the period of January 2000-January 2011 are presented in Figure 3.

Impact of Corn Price Volatility and Volatility of Financial Markets

For milk production, corn price is one of the major components of feed cost. Large swings in corn price may induce corresponding changes in milk price through changes in milk supply and consequently in production and prices of dairy products. A negative correlation between commodity return and stock return attracts a large flow of index investment into the agricultural commodity markets in an attempt to use commodity futures as a new asset class in the portfolio. As a result, agricultural commodities including corn are likely to be in the process of financialization and its market variation is somewhat linked with the financial market (Tang and Xiong 2010). In this section, we illustrate this point by applying a three-equation nonstructural vector autoregressive (VAR) model to investigate the impacts of variability in corn and financial markets on class III milk price volatility. Monthly measure of price volatility of corn nearest (closest to maturity) futures contracts is constructed in a similar manner previously described with respect to Class III milk futures. Volatility of financial market is represented by monthly average of the VIX index, the Chicago Board Options Exchange Volatility Index. VIX is a widely used measure of financial market volatility derived from the implied volatility of S&P 500 index options.

The vector autoregressive model (Greene 2003, Ch. 19) is specified as

(2) $$y_t = \mu + A_1 y_{t-1} + ... + A_p y_{t-p} + \varepsilon_t$$

where y_t is the 3×1 vector of endogenous variables including the class III futures price volatility, corn price volatility and the VIX index. The optimal lag order p is chosen as 2 in this case. Table 1 shows the estimation results for Eqn. (2). A Granger causality test is employed to answer the question as to whether the changes in corn or financial market volatility cause movements in class III price volatility (Granger 1969). The results are listed in Table 2. Here the null hypothesis is that the excluded (endogenous) variables don't Granger-cause the dependent variables in the individual equations. For class III price volatility, the null hypothesis is rejected for both corn price and financial market volatilities, which implies that both corn price volatility and variability in equity market Granger-cause the volatility of milk prices. It suggests that the class III milk market is not segmented from the financial market. Especially, during financial crises, prices of financial assets and dairy products tend to move together because of the shocks to purchasing power and demand factors. In addition, we obtained a significant test statistic for corn price volatility in the equation of VIX, providing the evidence of financialization of traditionally traded agricultural commodities.

The integrated relationship between corn, class III milk, and financial markets are further illustrated in the dynamic paths of adjustments of volatilities to shocks in the corn price volatility and financial market volatility, i.e., the impulse response estimates. Impulse responses to one standard deviation shocks to variation in corn and financial markets, along with 95% confidence intervals, are illustrated in Figure 4. Statistically significant responses in class III price volatility are revealed in response to shocks to volatilities in corn and equity markets. A shock to corn price volatility appears to exert a positive influence on class III price volatility at the very beginning then the influence becomes insignificant from the second month on. In contrast, a shock of equity market results in persistent response in the class III market starting from third month, with the responses remaining positive for about 5 months after the shock. This implies that a single shock to the corn price volatility can exert immediate (one month later) but short-lived effect on milk price volatility as dairy farmers can adjust to the shock quickly by transmitting the shock to consumers or switching to other feeds, or changing their production. The shock to equity market volatility can exert 3-month lagged but long-term effect on milk price volatility as the shock to equity market produce much larger and broader effect on the whole economy including the purchasing power of consumers.

Determinants of Class III Price Volatility

Following the theoretical and empirical work in the literature (e.g., Streeter and Tomek 1992; Chavas and Kim 2004) as well as discussions and findings in the previous sections, we include variables in three conceptual categories, flow of information, current economic information, and market structure, as the major determinants of Class III price volatility in the futures market. For the analysis of milk price volatility, the dependent variable is the variance of daily changes of the logarithms of milk prices in the first 20 days of each month from January 2000 to January 2010.[6] We pick prices from Class III milk futures contracts that are the closest to the maturity.

The components of the flow of information category in milk market are mainly seasonal effect. Both milk production and dairy product demand have strong seasonal components. While milk production peaks in the late spring, demand for most dairy products is highest in the late fall. We use harmonic variables to reflect seasonality because they can represent a smooth seasonal pattern in a parsimonious way. The seasonal components can be written as

$$(3) \qquad s_t = \sum_{i=1}^{3} [\alpha_i \cos(2\pi i m_t / 12) + \beta_i \sin(2\pi i m_t / 12)]$$

where m_t is the month of the year corresponding to the observation t.

To reflect the current economic condition, we include two measures of supply and use: monthly cheese use/supply ratio and the price change of U.S. dollars. Inelastic milk demand makes a small production disturbance to large monthly and annual price swings. Dairy product stocks held by private producers and government are a key component to understand extreme price volatility. We use the ratio of monthly total use of cheese over monthly supply (monthly production plus beginning stocks) of cheese to represent supply and demand condition of the Class III market as this milk type is primarily used for the manufacture of hard cheeses. The cheese production and stock data are collected from the Dairy Product Reports and maintained within the University of Wisconsin Understanding Dairy Markets website.[7]

As the U.S. dairy industry becomes more dependent in international dairy markets in

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[6] As illustrated in the previous section, volatility of Class III milk futures prices declines significantly after the first two or three weeks in each month. The estimation results are not sensitive to the actual days we use to calculate the variance once they are longer than 15 days, i.e., including the variance information for the first two weeks.

[7] Available at http://future.aae.wisc.edu.

recent years, it is more exposed to fluctuation in overseas production and changing currency rates. Return of the US dollar index (USDX) futures traded on Intercontinental Exchange (ICE) is employed to track price fluctuations of US dollar. The USDX futures contracts trade on an index that weighs dollar exchange rates with six component currencies including European euro, Japanese yen, British pound, Canadian dollar, Swedish krona, and Swiss franc.

Futures market structure information is reflected in the variable of speculation index. As defined in Working (1960), speculation index measures the speculation intensity relative to short hedging. The index is defined as the ratio of speculation short or long positions to total hedging positions. The data are collected from the U.S. Commodity Futures Trading Commission (CFTC), who classifies the futures positions as "commercial" and "noncommercial". Commercial positions are held for hedging purpose, while noncommercial positions mainly represent speculative activities for financial profits. Specifically the speculation index S is constructed using CFTC trader position data as

$$(4) \quad S = \begin{cases} 1 + SS/(HS + HL) \text{ if } HS > HL \\ 1 + SL/(HS + HL) \text{ if } HL > HS \end{cases}$$

where $SS(SL)$ denotes speculative noncommercial short (long) positions in the Class III milk futures market and $HS(HL)$ is short (long) hedged commercial positions. The speculation index in (4) measures the extent by which speculation exceeds the minimum level necessary to offset hedging positions. For data construction, weekly hedging and speculative position numbers are obtained from Historical Commitments of Traders reports (CFTC 2000-2011).

We also include the volatility in corn futures market and financial market (VIX) as they are identified as influencing factors on class III market volatility in the previous section. The estimation is done in the ordinary least square (OLS) regression with robust standard errors where the standard errors are estimated using the Huber-White sandwich procedure (White, 1980). Such robust standard errors are used to deal with problems such as heteroscedasticity and non-normality. The Durbin-Watson statistics of 1.98 doesn't detect the presence of autocorrelation in the residuals. The estimation results are presented in Table 3.

Figure 5 illustrates the seasonality pattern implied by the estimated parameters on the seasonality components. It indicates that class III futures price volatility peaks in summer months and holiday seasons, which are consistent with our observation. Large level of use relative to supply has positive and statically significant impact on milk price volatility. Class III price volatility is found to have statistically significant relationship with U.S. exchange rates showing that U.S. dairy product markets increasingly integrate with the international market and are influenced by the relative appreciation/depreciation of U.S. currency.

Speculation in the futures market, corn price volatility, and variability in the financial markets all have positive, though statistically insignificant, impacts on milk price volatility. One possible explanation for the insignificant results could be that input price variation has been taken into account by the economic condition in the end products such as cheese.

Conclusion

In this study, we illustrate that unique characteristics of milk pricing scheme and cash settlement feature of the milk futures contracts generate unique monthly volatility pattern of Class III milk prices. Its volatility gradually decreases as the USDA price announcement date approaching. VAR analysis indicates that volatilities in both corn futures market and financial market Granger-cause the milk price volatility, while the impact of financial market is more persistent. By focusing on the evolution of volatility in milk futures market, this study attempts to quantify relative importance of a set of determining factors driving milk price variation. Besides embedded seasonality patterns, market demand and supply condition in the cheese market and changes in the U.S. exchange rates are also found to have positive and statistically significant impacts on milk price volatility. The effect of speculation is positive but not significant.

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Table 1. Estimation results for VAR system (2) for milk price volatility (*mvol*), corn price volatility (*cvol*), and VIX.

Milk volatility		Corn volatility		VIX	
$mvol_{t-1}$	-0.04	$mvol_{t-1}$	-0.05**	$mvol_{t-1}$	0.01
$mvol_{t-2}$	0.002	$mvol_{t-2}$	0.003	$mvol_{t-2}$	-0.003
$cvol_{t-1}$	0.74***	$cvol_{t-1}$	0.37***	$cvol_{t-1}$	0.03
$cvol_{t-2}$	-0.58**	$cvol_{t-2}$	0.35***	$cvol_{t-2}$	0.09*
VIX_{t-1}	-0.78	VIX_{t-1}	0.11	VIX_{t-1}	1.06***
VIX_{t-2}	1.31***	VIX_{t-2}	-0.09	VIX_{t-2}	-0.25***
constant	1.23***	constant	0.07	constant	-0.01

Note: Single (*), double (**), and triple (***) asterisks denote significance at 0.10, 0.05, and 0.01levels, respectively.

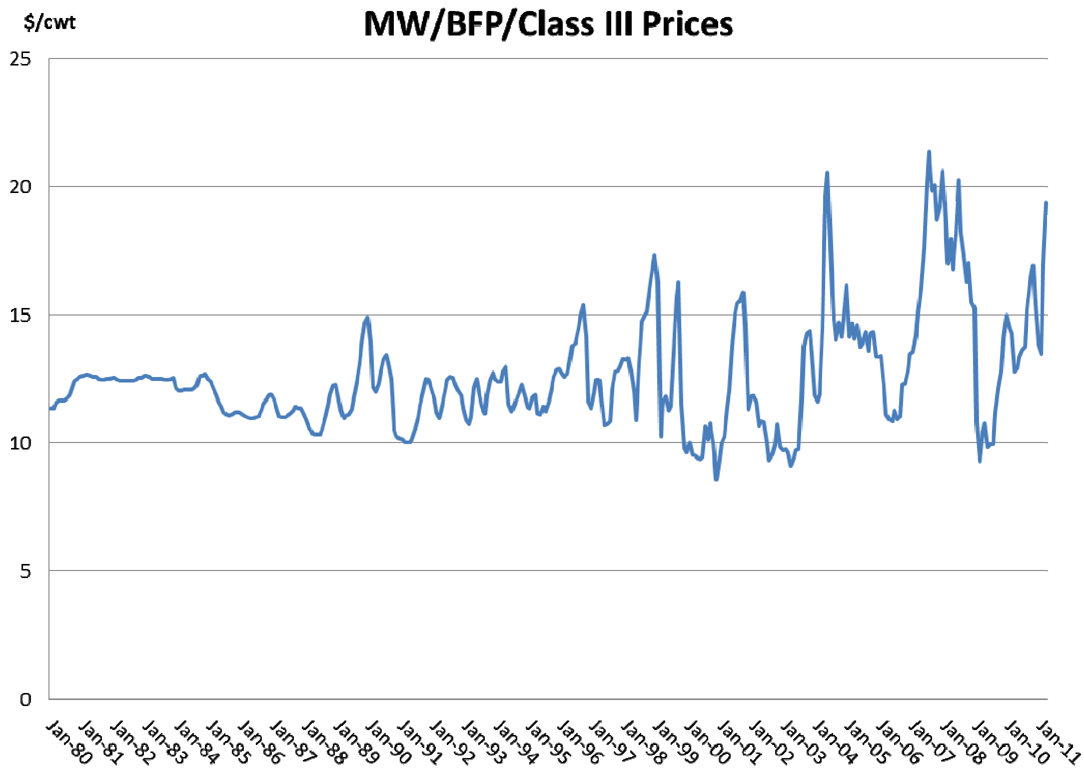
Table 2. Granger causality testing results for Eqn. (2).

Equation	Excluded	χ^2 statistics	$P > \chi^2$
mvol	*cvol*	7.50	0.02
	VIX	9.47	<0.001
	all	16.77	<0.001
cvol	*mvol*	4.63	0.10
	VIX	0.52	0.77
	all	6.04	0.20
VIX	*mvol*	0.48	0.79
	cvol	6.40	0.04
	all	7.62	0.11

Table 3. Estimation results for regression analysis

Variable	Estimate	Robust Standard Error	P value
Seasonal components			
cos_1	-0.16	0.35	0.65
cos_2	0.52	0.30	0.08
cos_3	0.24	0.28	0.39
sin_1	0.32	0.34	0.35
sin_2	0.33	0.33	0.32
sin_3	0.006	0.36	0.99
Cheese use/supply	0.54	0.31	0.08
USDX	0.62	0.31	0.05
Corn price volatility	0.18	0.32	0.58
Speculation index	0.027	0.16	0.86
VIX	0.11	0.32	0.73
Constant	1.19	0.23	<0.001

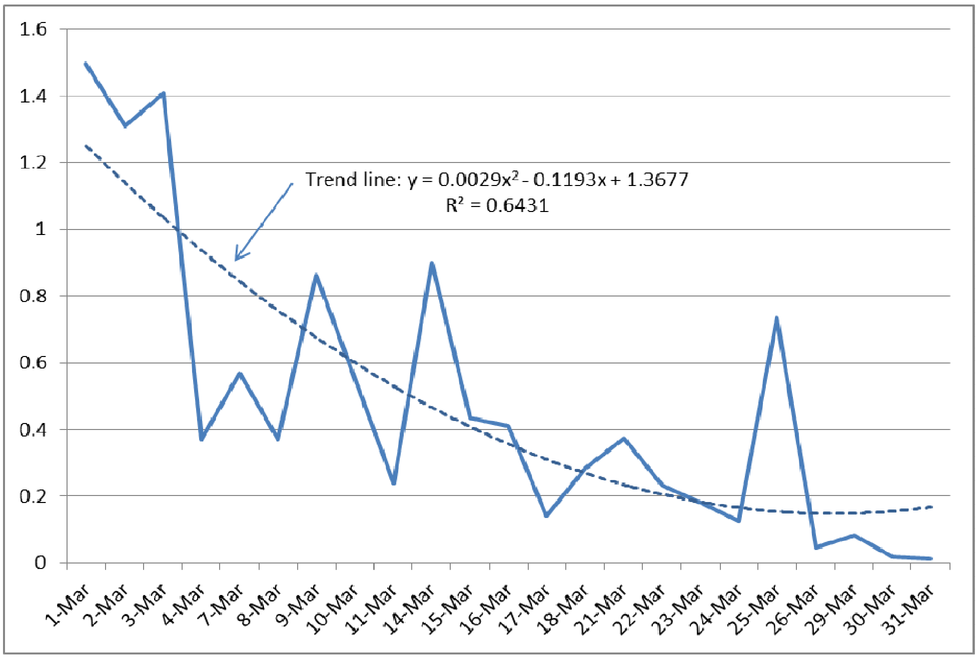
Figure 1. MW/BFP/Class III Prices (1980-2011).



Note: 1980-May 1995, the Minnesota-Wisconsin (MW) price; May 1995-December 1999, the Basic Formula Price (BFP); January 2000-present, the Class III price.

Figure 2. Daily Realized Volatility, March 2011 (upper panel) and Febuary 2011 (lower panel)

March 2011



Feburary 2011

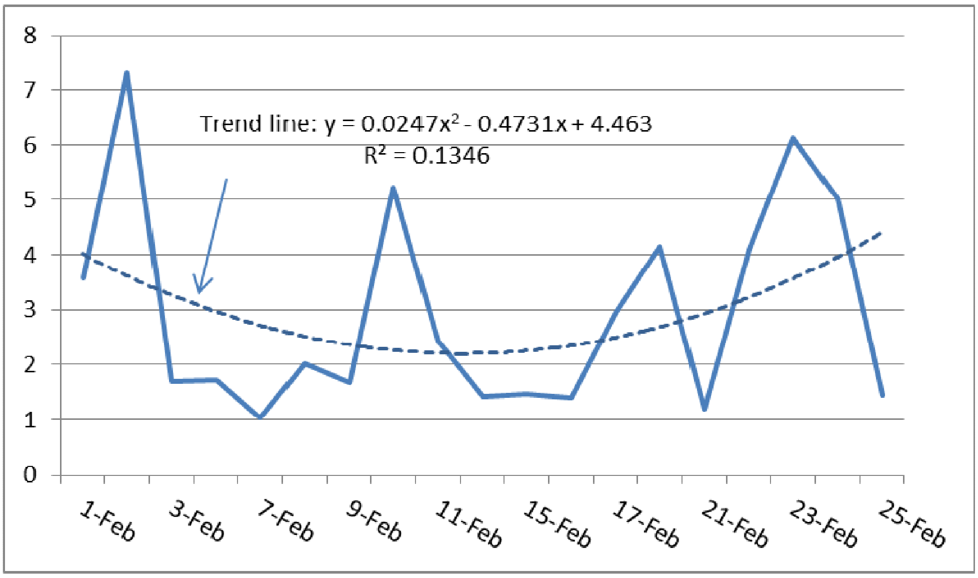


Figure 3. Monthly Volatility of Milk Futures Prices, Jan. 2000-Jan. 2011.

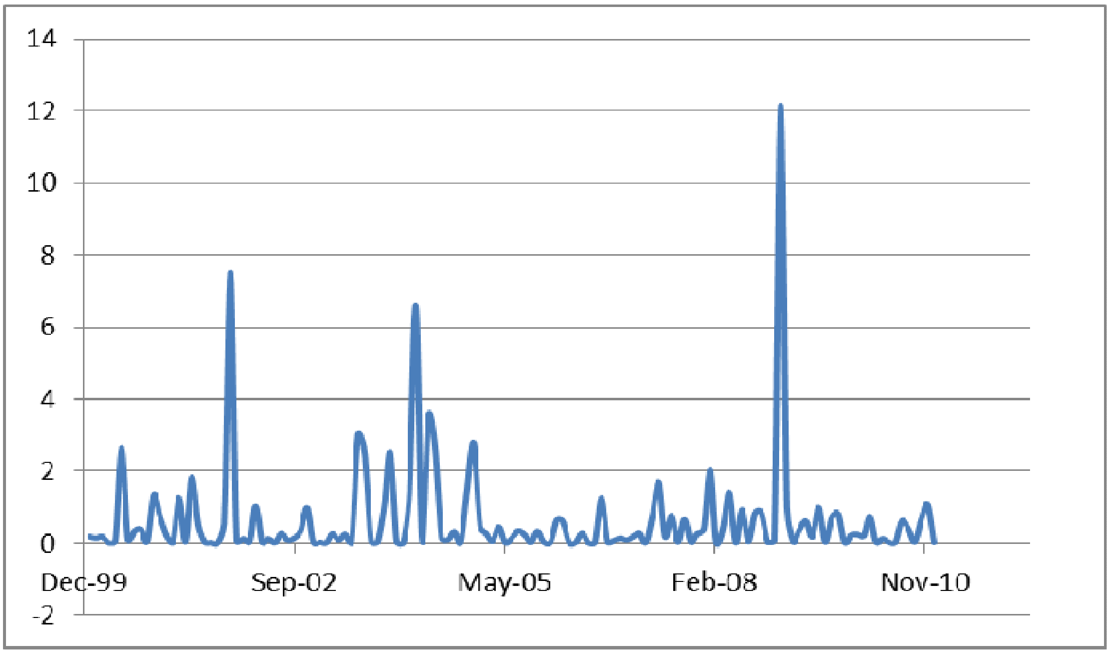
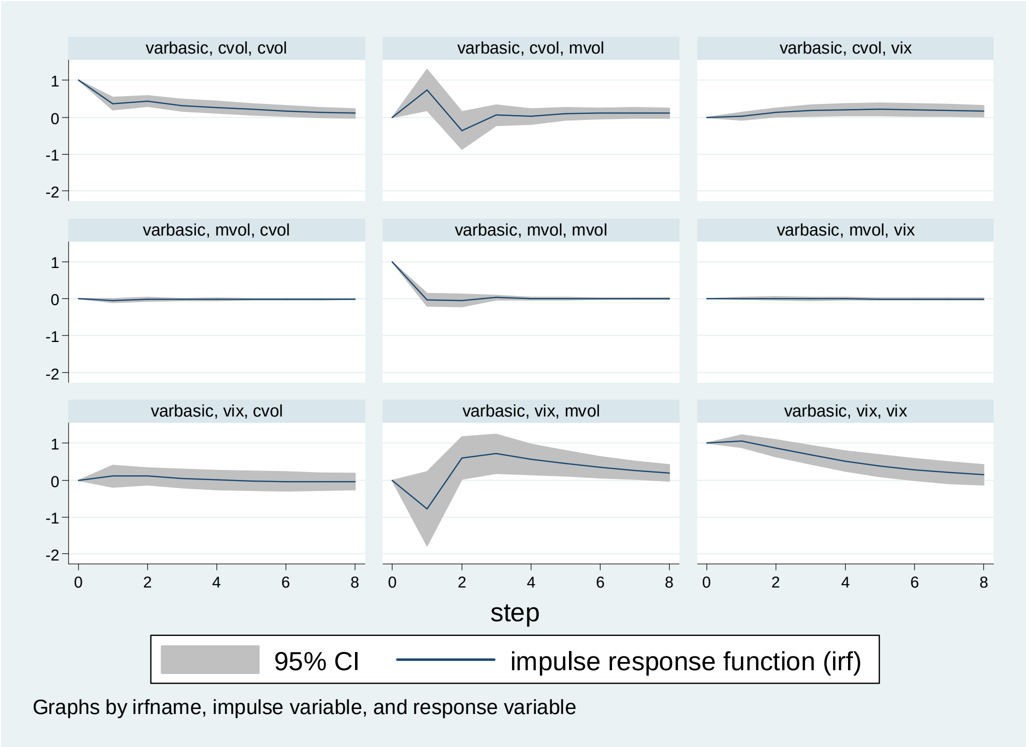


Figure 4. Impulse Responses of Volatilities of Corn Price, Milk Price and VIX.



Note: the first row is the impulse responses of corn price volatility, milk price volatility, and financial market volatility, respectively, to one standard deviation shock to variation in corn price; the second row is the impulse responses of corn price volatility, milk price volatility, and financial market volatility, respectively, to one standard deviation shock to variation in milk price; and the third row is the impulse responses of corn price volatility, milk price volatility, and financial market volatility, respectively, to one standard deviation shock to variation in financial markets.

Figure 5. Estimated Seasonality in Milk Price Volatility.