Price Discovery in the United States Dairy Industry

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Abstract

The organized Exchange spot (cash) cheese market is a private industry institution that has historically performed a primary price discovery function in the U.S. dairy industry. In addition to affecting cheese prices in contract cheese market, the Exchange spot cheese prices have influenced prices paid for milk at the farm level that are set within the system of Federal Milk Marketing Orders (FMMOs). The effects that the Exchange spot cheese market has on FMMOs milk pricing attract increased attention in light of the most recent concerns about increasing milk price volatility and its effect on the dairy farm profitability. While the design of milk pricing within FMMOs has evolved over the last three decades, the effect of the Exchange spot cheese prices on FMMOs milk pricing has intensified. This research conducts an econometric analysis of the behavior (i.e. the level and volatility) of the Exchange spot cheese price over three FMMOs milk pricing regimes. [JEL Classification: L1; Q1; K2].

1. INTRODUCTION

The United States dairy industry pricing institutions are complex. They represent a unique interaction of administered pricing of milk at the farm-first-handler level and private (contract) pricing of fluid milk and manufactured dairy products (cheese, butter, yogurt, ice-cream, etc.) at the wholesale and retail level. The core of the U.S. dairy industry pricing system is the government pricing of milk at the production (farm) stage implemented through the system of Federal and State Milk Marketing Orders[1].

The organized Exchange spot (cash) cheese market is a private industry institution that has performed a primary price discovery function in the U.S. dairy industry (Hamm & March, 1995; Mueller et al., 1996; Manchester & Blayney, 1997; U.S. Government Accountability Office Report, 2007). The National Cheese Exchange (NCE) located in Green Bay, WI performed this function during the period of 1974-1997. Since April 1997, after the NCE dissolution, the spot cheese market functions at the Chicago Mercantile Exchange (CME)[2]. First, the Exchange spot cheese prices have been used as reference prices in cheese contracts used to transact more than 90% of cheese produced in the country. Second, the Exchange spot cheese prices have influenced prices paid for milk within the system of Federal Milk Marketing Orders (FMMOs).

While the design of milk pricing within FMMOs has evolved over the last three decades, the effect of the Exchange spot cheese prices on milk pricing has intensified (Chart 1). In particular, beginning in 1995, the NCE cheddar cheese price was included in the FMMOs milk price determination procedure. Furthermore, in 2000 when a new milk pricing system was introduced

[1] Fluid milk pricing at the wholesale and retail level is within the legal authority of individual States. Some States have milk price control regulations that affect fluid milk prices at the wholesale and/or retail level; for example, Pennsylvania and New York State.

[2] The term "Exchange" is used in this article to refer to the spot (cash) cheese market regardless of its geographic location in different periods of history.

within FMMOs, cheese price was included in a number of price formulas. The U.S. Department of Agriculture Agricultural Marketing Service uses survey-based wholesale cheddar cheese prices to determine wholesale cheese price used in these formulas on a monthly basis. The survey-based wholesale cheddar cheese prices correspond to the first-handler level and are practically at the same level as the CME spot cheddar cheese prices (Table 1 and Figure 1).

In light of the effects that the Exchange spot cheese prices have had on milk pricing, the conduct and performance of the Exchange spot cheese market have periodically raised concerns about the potential for market manipulations (Mueller et al., 1996, 1997; Mueller & Marion, 1997, 2000; Martin, 2004, 2005; U.S. Government Accountability Office Report, 2007; Shields, 2009, 2010; Carstensen, 2010; Gould, 2010; U.S. Department of Justice and U.S. Department of Agriculture workshops “Agriculture and Antitrust Enforcement Issues in Our 21st Century Economy”, 2010a,b; U.S. Department of Agriculture Dairy Industry Advisory Committee Report, 2011).

The Exchange spot cheese market is a thin (a low volume) market and is concentrated, where a relatively small number of sellers and buyers trade on a regular basis. These few cheese sellers and buyers determine cheese prices that eventually affect milk prices received by all dairy farmers in the country. The Exchange spot cheese market performance issues are intensified by the most recent concerns about the overall performance of FMMOs milk pricing system: increasing volatility of milk prices received by dairy farmers and its effects on dairy farm profitability (U.S. Department of Agriculture Dairy Industry Advisory Committee Report, 2011).

The objective of this research is to analyze the conduct and performance of the Exchange spot cheese market, with a particular focus on the spot cheddar cheese price behavior during three FMMOs milk pricing regimes: Minnesota-Wisconsin price regime, Basic Formula Price and modern Multiple Component Pricing regime. The changes in the FMMOs milk pricing method and in the Exchange institutional environment are taken into account while evaluating changes in the patterns of level and volatility of the Exchange spot cheddar cheese prices during the period of 1983 to 2015.

The paper is organized as follows. Section 2 provides an overview of the Exchange spot cheese market. Section 3 provides a brief discussion of FMMOs milk pricing and highlights increasing effect of cheese prices on FMMOs milk pricing. Section 4 presents a descriptive statistical analysis. Section 4 develops an econometric model of the Exchange cheese price behavior. Section 5 discusses the estimation results, and is followed by the conclusion.

2. THE EXCHANGE SPOT (CASH) CHEESE MARKET[3]

Since May 1997, the spot (cash) cheese trade takes place at the Chicago Mercantile Exchange spot cheese market (CME). The dissolution of the National Cheese Exchange (NCE), and the move of the spot cheese market to CME were accompanied by a number of changes in some of the trading rules and regulatory oversight (U.S. Government Accountability Office, 2007). The changes relating to trading rules included a shift from a weekly trade at NCE to a daily trade at CME and introduction of anonymous trading process at CME (traders are represented by professional brokers).

The CME spot cheese market structural characteristics and key trading rules remained similar to the NCE. Cheddar cheese traded on the CME is a highly standardized product, and is currently represented by two styles: cheddar cheese sold in 40 pound blocks and cheddar cheese sold in 500 pound barrels[4]. Barrel cheddar is used in further processing to manufacture processed

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[3] A discussion presented in this section is based on Hamm and March (1995); Mueller et al. (1996), Manchester and Blayney (1997) and U.S. Government Accountability Office Report (2007).

[4] Although a number of cheese varieties were traded at the Exchange in different periods of history, American type cheeses were always dominant. Since early 1980s, only cheddar cheese has been traded at the Exchange. Its prices

cheeses, cheese spreads and similar products. Block cheddar is used to make cut and wrapped natural cheeses. Cheddar cheese is the only cheese variety traded on CME.

The CME spot cheese prices are stated per pound of cheese, but the volume traded is in carloads, each containing between 40,000-44,000 pounds of cheese[5]. Cheese trading takes place on a daily basis during each working day. Trading does not have to take place every single day, and there may be instances when no trade occurs on a particular day or in a number of consecutive days. The identities of traders are not publicly known; the traders are represented by professional brokers.

The CME spot cheese market is a thin (a low volume) market, where typically less than two percent of the total volume of cheese produced in the U.S. is traded (Table 2). In addition, CME spot cheese market is concentrated. Although there are 30-40 members, only a few buyers and a few sellers actively trade on a regular basis (U.S. Government Accountability Office Report, 2007). These are large proprietary firms involved in cheese manufacturing and large agricultural cooperatives. The CME cheese traders are also active participants in contract market.

During the period of 1999-2007, two market participants bought 74% of all block cheese, and three market participants sold 67% of all block cheese (U.S. Government Accountability Office Report, 2007). Four market participants bought 56% of all barrel cheese, and two market participants sold 68% of all barrel cheese. In addition to a low volume of trade taking place on the CME spot market relative to the total industry volume and a high concentration of sales and purchases, transactions are infrequent. For example, during the period of 1998-2006, the average

have been used as reference prices in pricing not only cheddar cheese but other cheese varieties as well (Manchester & Blayney 1997).

[5] The CME Rulebook Chapter 11 (2015) establishes requirements relating to the cheese styles, grades, age, moisture content, color, freight charges, weight and a variety of other conditions representing a standardized set of trading rules.

number of transactions per trading session was in the range of 0.4-2.2 for barrel cheese, and it was in the range of 1.4-3.5 for block cheese (U.S. Government Accountability Office Report, 2007).

The closing price rule is a key trading rule that affects the conduct of traders and consequently the CME spot cheese market performance. At the end of each trading day a closing price is announced. The closing price can be based on the actual sale, unfilled bid or uncovered offer. Unfilled bids indicate willingness to buy at a stated price, and uncovered offers indicate willingness to sell. The closing price is the last actual sale price or the last unfilled bid, if it is higher than the last actual sale price, or the last uncovered offer, if it is lower than the last actual sale price. In addition to actual sales, unfilled bids and uncovered offers are important determinants of the CME closing spot cheese prices.

The closing spot cheese prices affect the reference prices used in cheese contracts. Depending on the design of contract pricing systems, closing price corresponding to a particular day or the average weekly price (or a similar modification) can be used as the reference price in cheese contracts. Cheese pricing systems (strategies) in contract market vary with the type of buyers (food service establishments, institutional buyers or retailers) and the degree of product differentiation (Hayenga, 1979; Mueller et al., 1996; Manchester & Blayney, 1997).

For example, at the first-handler level, contract prices are tied to the Exchange price on a day of cheese production plus a premium or discount reflecting cheese quality characteristics. For institutional buyers, a monthly or a weekly price list is developed, and its prices are tied to the Exchange price. Cheese prices in contracts with large food-service chains are based on the Exchange price corresponding to the previous month. Prices of highly differentiated cheese products with well-developed brands sold at the retail level are typically based on weekly price lists. These prices tend to be loosely related to the Exchange prices and are affected by other factors such as the magnitude of marketing costs (including merchandizing and advertising expenditures) and margin consideration.

3. FEDERAL MILK MARKETING ORDERS MILK PRICING AND THE EXCHANGE SPOT CHEESE MARKET[6]

The FMMOs classified pricing system establishes the minimum prices for Grade A milk that regulated handlers have to pay for raw milk based on the final use of milk, currently represented by four milk classes. Class III milk price, which is the price paid for milk used in cheese manufacturing, is a mover of the overall FMMOs milk pricing structure. Given that milk is the main input used in cheese manufacturing, the increasing over time interaction of FMMOs Class III milk pricing and the Exchange spot cheese pricing represents a particular interest in light of price discovery in the U.S. dairy industry (Chart 1). This interaction affects the conduct and performance of the Exchange spot cheese market, and consequently the performance of milk pricing within FMMOs. In particular, Figure 1 indicates that the Exchange spot cheddar cheese price, FMMOs Class III milk price and all-milk price received by dairy farmers tend to move in a similar manner.

3.1. Minnesota-Wisconsin Price (M-W price regime): 1960s – May 1995

During the period of 1960s-1995, Class III milk price was based on unregulated Grade B milk price paid by manufactures of cheese, butter and non-fat dry milk in Minnesota and Wisconsin. Until the beginning of 1990s, active Federal Dairy Product Price Support Program (DPPSP) established support prices for manufactured dairy products (cheese, butter, non-fat dry milk), which provided a price floor for milk used for manufacturing purposes. When the M-W price was below the milk price support level, the latter was used as a base price for Class III milk price within

[6] Milk pricing in the U.S. dairy industry is discussed in Erba and Novakovic (1995), Manchester and Blayney (1997, 2001) and Brown et al. (2010).

FMMOs. In early 1990s, DPPSP practically became inactive, due to a decrease in the price support level. During this FMMOs milk pricing regime, the National Cheese Exchange spot cheese prices influenced Grade B milk price, which in turn affected manufacturing milk price within FMMOs.

3.2. Basic Formula Price (BFP regime): June 1995-December 1999

In June 1995, Basic Formula Price (BFP) replaced M-W price[7]. While unregulated Grade B milk price paid in Minnesota and Wisconsin (M-W price) was still an element in the Class III milk price determination procedure, a new formula including cheese price was introduced. The National Cheese Exchange spot price for cheddar cheese sold in 40 pound blocks was originally used in this formula. Starting in May 1997, when the spot cheese market was moved from NCE to CME, the U.S. Department of Agriculture National Agricultural Statistics Service (USDA NASS) survey-based price of cheddar cheese sold in 40 pound blocks replaced the NCE spot cheese price in the milk price formula.

3.3. Multiple Component Pricing (MCP regime): 2000-present

A completely new milk pricing system was introduced in January 2000. Class milk prices are calculated using a series of price formulas, which use wholesale prices of manufactured dairy products to determine the value of key milk components and consequently Class milk prices. In particular, Class III milk price is affected by wholesale prices of cheese, butter and whey, with the cheese price being the key determinant[8]. Cheese price also affects Class I milk pricing (milk used in manufacturing fluid milk products). In particular, a formula used to calculate an appropriate milk component price is the same as the one used in the Class III milk price calculation procedure. The cheese price used in milk price formulas is determined by the USDA Agricultural Marketing

[7] BFP was a temporary alternative because the share of Grade B milk was expected to decline.

[8] A detailed discussion of the design of Class III milk pricing during the analyzed FMMOs milk pricing regimes and an econometric analysis of the effect of the Exchange spot cheese prices on FMMOs Class III milk price over time is presented in Bolotova (2017).

Service (USDA AMS) by using the USDA NASS survey-based wholesale prices of cheddar cheese sold in 500 pound barrels and 40 pound blocks. The USDA NASS survey-based cheddar cheese prices correspond to the first-handler level and are practically at the same level as the CME spot cheddar cheese prices (Table 1 and Figure 1). This is because surveyed cheese manufacturing plants report cheese prices that are referenced to the CME spot cheese prices in cheese contracts.

4. DESCRIPTIVE STATISTICAL ANALYSIS

Descriptive statistical analysis is used to evaluate patterns of the Exchange spot cheese market trading activities (Table 2 and Figure 2) and the behavior (i.e. changes in the level and volatility) of the Exchange spot cheese prices, Class III milk price and corresponding margins over three milk pricing regimes (Table 3 and Figure 1)[9]. Trading activities, which include actual sales, unfilled bids and uncovered offers, characterize the conduct of cheese sellers and buyers. The behavior of the Exchange spot cheddar cheese price and wholesale cheese margin reflects the spot cheese market performance.

For the purpose of empirical analysis, the Minnesota-Wisconsin price (M-W price) regime is split into two sub-periods. The first period (January 1983 – December 1989) is characterized by a substantial degree of government intervention in cheese purchases and sales (i.e. "active DPPSP"). The second period (January 1990 – May 1995) is characterized by a minimal degree of government intervention ("inactive DPPSP").

4.1. The Exchange Spot Cheese Market: Conduct

An analysis of the patterns of the Exchange spot cheese market trading activities over three milk pricing regimes reveals that the Exchange was least actively used in M-W price regime and was most actively used in BFP regime, followed by MCP regime (Table 2). The yearly average total

[9] Data sources are discussed in the Appendix.

trading activity (the sum of actual sales, unfilled bids and uncovered offers) is the lowest in M-W price regime with active DPPSP: 592 carloads. The yearly average share of actual sales is 56%, and the yearly average share of unfilled bids and uncovered offers is 44%. During this regime, the yearly average trading activity increased to 781 carloads in the sub-period with inactive DPPSP. The yearly average percentage of the Exchange cheddar cheese sales in the total cheddar cheese production was less than one percent.

A dramatic increase in the yearly average total trading activity takes place between M-W price and BFP regimes. The BFP regime yearly average total trading activity is 2,033 carloads. The yearly average share of actual sales in the total trading activity increases to 69% in BFP regime. The yearly average share of unfilled bids and uncovered offers is 31%. The yearly average percentage of the Exchange cheddar cheese sales in the total cheddar cheese production is approximately 2%, which is more than two times higher than the M-W price regime percentage.

During MCP regime, the yearly average total trading activity is slightly lower than in BFP regime: 1,765 carloads. The MCP regime yearly average share of actual sales in the total trading activity is 56%. Consequently, the MCP regime yearly average share of unfilled bids and uncovered offers is 44%. The yearly average percentage of actual sales, unfilled bids and uncovered offers in the total trading activities is at the same level in MCP regime and M-W price regime with active DPPSP. The yearly average percentage of cheddar cheese traded at the Exchange (relative to the overall cheddar cheese production) decreases in MCP regime, as compared to BFP regime, and reaches 1.33%.

4.2. The Exchange Spot Cheese Market: Performance

During the two sub-periods of M-W price regime, the monthly average cheese and milk prices practically do not change, but their volatility (measured using the coefficient of variation) increases by 14% during the second sub-period. The patterns of changes in the level and volatility of cheese prices and milk price are similar during three milk pricing regimes. While changes in the monthly average cheese and milk prices are rather small in magnitude between M-W price and MCP regimes, changes in the volatility of these prices are dramatic. As cheddar block price and cheddar barrel price behave in a similar manner, cheddar block price is used in the following discussion.

The monthly average cheddar block price increased from $1.27/pound in M-W price regime (inactive DPPSP) to $1.43/pound in BFP regime (or by 12.6%), with a consequent increase to $1.55/pound in MCP regime (or by 8.4%). The monthly average milk price increased from $11.76/cwt in M-W price regime (inactive DPPSP) to $12.90/cwt in BFP regime (or by 9.7%), followed by an increase to $14.94/cwt in MCP regime (or by 15.8%). The monthly average cheese price increased by 22%, and the monthly average milk price increased by 27% during the overall period of time.

The cheese price volatility (measured using the coefficient of variation) increased by 63% between M-W price and BFP regimes and by 54% between BFP and MCP regimes, with an overall increase of 150%. The milk price volatility increased by 75% between M-W price and BFP regimes and by 79% between BFP and MCP regimes, with an overall increase of 213%. While the volatility of cheese price and milk price was of the same magnitude during M-W price regime, the volatility of milk price has increased at a higher rate over the analyzed period of time.

The monthly average cheddar block margin[10] increased from 7.55% in M-W price regime (inactive DPPSP) to 9.51% in BFP regime (or by 26%). In MCP regime, the monthly average margin decreased to 4.62% (or by 51%), relative to BFP regime. Overall, the monthly average

[10] The cheddar barrel (block) margin is calculated as the difference between barrel (block) price and milk price expressed as a percentage of the barrel (block) price. The original Class III milk price ($/cwt) is divided by 10 to represent the cost of milk incurred to produce one pound of cheese. The margin reflects the cheese manufactures' mark-up over the major input (milk) cost.

margin decreased by almost 40% between M-W price regime and MCP regime. The margin volatility (measured using the coefficient of variation) increased by 74% between M-W price and BFP regimes, followed by an increase by 279% between BFP and MCP regimes, with the overall increase of 559%.

The empirical evidence presented in this section indicates that the Exchange spot cheese market reacted to changes in its institutional environment, including changes in FMMOs milk pricing regimes and changes in trading rules facilitated by the move of the spot cheese market from NCE to CME during BFP regime (1995-1999). The largest magnitude increase in the average cheese price level and the largest magnitude increase in the cheese price volatility correspond to BFP regime. The two changes in the Exchange institutional environment that might have contributed to the observed cheese price behavior in BFP regime, relative to M-W price and MCP regimes, are the following.

First, when BFP was introduced, NCE spot cheddar block cheese price was included in a formula used to determine manufacturing milk price within FMMOs. Second, when the spot cheese market was moved from NCE to CME, a weekly trade at NCE was replaced with a daily trade at CME. The latter change in trading rules might have contributed to an increase in the cheese price volatility during BFP regime. An econometric analysis presented in the following sections provides a more rigorous evaluation of changes in the behavior of the Exchange spot cheese price during the analyzed FMMOs regimes.

5. ECONOMETRIC MODEL

An autoregressive conditional heteroscedasticity (ARCH) model is used to evaluate the behavior (i.e. changes in the level and volatility) of the Exchange spot cheddar cheese price over the analyzed FMMOs pricing regimes. A general specification of the ARCH(m) model used in this research is represented by equations [1] and [2] (Wooldridge, 2003)[11].

Equation [1] describes the conditional mean process, and equation [2] describes the conditional variance process over time. In the conditional mean equation, the dependent variable (Y) is a function of a set of exogenous variables (***Z***). The dependent variable in the conditional variance equation (i.e. the current variance of Y) is the squared error term from the conditional mean equation; it is modeled as a function of the past variances (i.e. the ARCH effect). The conditional variance equation can be expanded by including a set of exogenous variables of interest that are hypothesized to affect the conditional variance process over time .

$$y_t = \psi_0 + \overline{\psi} \times \overline{z_t} + u_t \text{ [12]} \qquad [1]$$

$$u_t^2 = \alpha_0 + \alpha_1 \times u_{t-1}^2 + \alpha_2 \times u_{t-2}^2 + ... + \alpha_m \times u_{t-m}^2 + v_t \text{ [13]} \qquad [2]$$

Equations [3] and [4] represent a specification of the ARCH(1) model to be estimated.

$$CP_t = \psi_0 + \psi_1 \times MP_{t-1} + \psi_2 \times MP_{t-2} + \gamma_1 \times BFPWT_t + \gamma_2 \times BFPDT_t + \gamma_3 \times MCP_t + \overline{\theta} \times \overline{M}_t + u_t \qquad [3]$$

$$u_t^2 = \alpha_0 + \alpha_1 \times u_{t-1}^2 + \lambda_1 \times BFPWT_t + \lambda_2 \times BFPDT_t + \lambda_3 \times MCP_t + v_t \qquad [4]$$

CP_t (\$/pound) is the average Exchange cheddar cheese price (the average of cheddar block and cheddar barrel) in month t. Milk is the key input used in cheese manufacturing, and milk cost

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[11] A noise process u_t satisfying variance equation [2] is described as an autoregressive conditional heteroscedastic process of order m, denoted as ARCH(m).

[12] u_t is a white noise, $E(u_t) = 0$, $E(u_t u_s) = \sigma^2$ for $t = s$ and 0 otherwise.

[13] The sufficient stationarity (regularity) condition requires $\alpha_0 > 0$ and $\alpha_j \geq 0$ for all $j \leq m$.

typically represents more than 90% in the wholesale cheese price at the first-handler level. The announced FMMOs Class III milk price (price paid for milk used in cheese manufacturing) is used as an independent variable. Class III milk price is announced in $ per hundredweight (100 pounds). For the purpose of empirical analysis, Class III milk price is converted in $ per pound to represent the cost of milk incurred to produce one pound of cheese[14]. Class III milk price is announced before or on the 5th of the month following the month to which this price applies. Therefore, during month *t* cheese industry participants know only the previous month(s) Class III milk price. MP_{t-1} ($/pound) and MP_{t-2} ($/pound) are the announced Class III milk prices in month *t-1* and *t-2*, respectively[15].

BFP and MCP are referred to FMMOs pricing regimes, which effects on the Exchange cheese price are modeled using a set of binary variables. To capture the effect of a move of the spot cheese market from NCE to CME, and in particular, the effect of a shift from a weekly trade at NCE to a daily trade at CME, BFP regime is further split into two periods[16]. $BFPWT_t$ is a binary variable, which is equal to 1, if a cheese price (variance) observation belongs to the first part of the Basic Formula Price regime, when the spot cheese trade took place on a weekly basis (NCE: 05/1995-04/1997 and CME 05/1997-08/1997) and is equal to 0 otherwise. $BFPDT_t$ is a binary variable, which is equal to 1, if a cheese price (variance) observation belongs to the second part of the Basic Formula Price regime, when the spot cheese trade took place on a daily basis (CME:

[14] Typically 10 pounds of milk are required to produce one pound of cheese. The announced Class III milk price measured in $/cwt is divided by 10 to be expressed in $/pound.
[15] Regression diagnostics, including explanation of the number of lagged milk prices included as independent variables, are discussed in the Appendix.
[16] An alternative approach to split BFP regime is by using NCE period and CME period. While the spot cheese market was moved from NCE to CME in May 1997, a daily spot cheese trade was introduced in September 1998. An alternative specification of the econometric model by using NCE and CME periods within BFP regime was estimated. The results are available from the author upon the request.

09/1997 – 12/1999) and is equal to 0 otherwise. MCP_t is a binary variable, which is equal to 1, if a cheese price (variance) observation belongs to the Multiple Component Pricing regime (01/2000-present) and is equal to 0 otherwise. The observations belonging to the Minnesota-Wisconsin price regime (01/1983-04/1995) represent the reference group. $\overline{M_t}$ is a set of monthly binary variables.

Two econometric models differing due to the number of observations included in the econometric analysis are estimated. Model 1 is based on a smaller number of observations included in M-W price and MCP regimes. This approach allows to evaluate more precisely the immediate response of the Exchange spot cheese price to changes in the design of milk pricing during the analyzed FMMOs regimes. In Model 1, M-W price regime with inactive DPPSP (01/1990 – 05/1995) is used as a reference group, and MCP regime is represented by the first four years (01/2000 – 12/2003). In Model 2, the entire M-W price regime (01/1983 – 05/1995) is a reference group, and MCP regime is represented by all available years (01/2000 –12/2015).

The estimated coefficients for FMMOs pricing regime binary variables are of a particular interest. The estimated coefficients in the cheese price equation, γ_1, γ_2 and γ_3, capture the shifts in the cheese price level in BFPWT regime/period, BFPDT regime/period and MCP regime, respectively, relative to M-W price regime. The estimated coefficients in the cheese price variance equation, λ_1, λ_2 and λ_3, capture the shifts in the cheese price variance in BFPWT regime/period, BFPDT regime/period and MCP regime, respectively, relative to M-W price regime. Finally, the estimated coefficient for milk price, ψ_1 (or $\psi_1+\psi_2$ in the case of the cumulative effect), is a vertical price transmission coefficient, which is also referred to as cost pass-through (CPT). Under the assumption of a perfectly competitive pricing CPT is equal to one. If a seller market power is present, CPT may be greater than one (a non-linear demand assumption) or smaller than one (a linear demand assumption)[17]. CPT is equal to 0.5 under the assumption of monopoly pricing in a linear demand market. A series of additional T-tests is conducted to evaluate the magnitude of the estimated CPT. ARCH(1) models are estimated using the Ordinary Least Squares (OLS) estimation procedure.

6. ESTIMATION RESULTS

The OLS estimation results for two ARCH(1) models and outcomes of a series of T-tests used to test a set of specific hypotheses of interest are summarized in Table 4. The estimation results are generally consistent across the two models. The following discussion focuses on the estimation results for Model 1, which is based on a smaller sample. The only difference in the estimation results between Model 1 and Model 2 is in the pattern of statistical significance of the estimated coefficients for FMMOs regime binary variables in the conditional mean equation.

6.1. Model 1: Conditional Mean Equation

The variation in the lagged milk prices, a set of monthly binary variables and binary variables for milk pricing regimes explains 70% in the variation of the Exchange spot cheddar cheese price. The majority of the estimated coefficients are statistically significant at the 10% significance level. A set of monthly binary variables is statistically significant as a group (Table 4: F-test p-value is 0.0006).

The estimation results indicate that there are statistically significant differences in the average Exchange spot cheese price level during the analyzed regimes/periods. The estimated coefficients for milk pricing regime binary variables indicate that, while controlling for variation in milk price, the average cheese price is approximately $0.05/pound and $0.12/pound higher in BFP regime (BFPWT and BFPDT periods, respectively), and is $0.03/pound higher in MCP

[17] A discussion of the cost pass through magnitude is presented in Cotterill (1998), Carman and Sexton (2005) and Bolotova and Novakovic (2012).

regime, relative to the reference group represented by M-W price regime (inactive DPPSP). These estimated coefficients are statistically significant. A series of additional T-tests is used to evaluate whether there are statistically significant differences in the average cheese price among all analyzed regimes/periods.

A statistically significant *increase* in the average cheese price is observed between M-W price regime (inactive DPPSP) and the first part of BFP regime with weekly trading (Table 4: T-statistic is 2.71). Another statistically significant *increase* in the average cheese price is observed during the second part of BFP regime with daily trading, relative to the first part of this regime with weekly trading (Table 4: T-statistic is 1.36). A statistically significant *decrease* in the average cheese price is observed in MCP regime (daily trading), relative to the second part of BFP regime with daily trading (Table 4: T-statistic is -1.61). There is no statistically significance difference between the average cheese price in MCP regime (daily trading) and BFP regime with weekly trading (Table 4: T-statistic is -0.59).

The estimated coefficient for the previous month milk price (i.e. the milk price known during the current month) is equal to 0.98, which indicates that a $0.10/pound increase (decrease) in Class III milk price announced at the beginning of the current month causes a $0.098/pound increase (decrease) in the average cheese price corresponding to the same month. This estimated coefficient characterizes the current month cost pass-through (CPT), which is practically complete. As indicated by an additional T-test, this CPT is not statistically different from 1 (Table 4: T-statistic is -0.15). This CPT magnitude is consistent with a perfectly competitive pricing.

The cumulative effect of two lagged milk price variables is 0.62, the CPT magnitude indicating an incomplete cost pass-through. As indicated by two additional T-tests, this coefficient is statistically smaller than one (CPT for a perfectly competitive pricing) and is statistically greater than 0.5 (CPT for a monopoly pricing, linear demand) (Table 4: T-statistics are -5.47 and 1.70, respectively)[18]. This CPT is consistent with the profit-maximizing behavior of oligopoly operating in the market environment with a linear demand and constant marginal cost.

6.2. Model 1: Conditional Variance Equation

The variation in the lagged price variance and binary variables for milk pricing regimes explains approximately 33% in the variation of the conditional cheese price variance. The estimation results indicate that there are statistically significant differences in the conditional cheese price variance during the analyzed regimes/periods. The estimated coefficients for milk pricing regime binary variables are 0.003 and 0.033 for BFP regime (BFPWT and BFTDT, respectively) and 0.007 for MCP regime. These estimated coefficients indicate increases in the conditional cheese price variance in these regimes/periods, relative to M-W price regime (inactive DPPSP). A series of additional T-tests is used to evaluate whether there are statistically significant differences in the conditional cheese price variance among all analyzed periods.

The increase in the conditional cheese price variance is not statistically significant between M-W price regime (inactive DPPSP) and the first part of BFP regime with weekly trade (Table 4: T-statistic is 1.04). The *increase* in the conditional cheese price variance between the first period of BFP regime with weekly trade and the second period with daily trade is statistically significant (Table 4: T-statistic is 6.26). Furthermore, a statistically significant *decrease* in the conditional cheese price variance is observed during the following MCP regime (Table 4: T-statistic is -5.73). The *increase* in the conditional cheese price variance between the first part of BFP regime with weekly trade and MCP regime (daily trade) is statistically significant (Table 4: T-statistic is 1.33).

[18] A one-tailed T-test is used to interpret the outcomes of these tests. A note to Table 4 explains this testing procedure.

By far the largest magnitude increase in the cheese price variance corresponds to the period when daily cheese trade was introduced at CME during BFP regime.

The estimation results of Model 2 based on the overall sample exhibit a similar pattern in both the conditional mean and conditional variance equations. The pattern of statistical significance of the estimated coefficients in the conditional variance equation in Model 2 is the same as in Model 1. However, the pattern of statistical significance of the estimated coefficients in the conditional mean equation is different. While all estimated coefficients for milk pricing regime binary variables are statistically significant from the reference group (M-W price regime), the estimated coefficients are not statistically significant from one another.

In summary, empirical evidence provided by the econometric analysis in general is consistent with empirical patterns revealed by the descriptive statistical analysis. There is empirical evidence supporting a statistically significant increase in the average Exchange spot cheddar cheese price (while controlling for variation in milk price) coinciding with the introduction of BFP regime, when the NCE cheddar block price was included in a formula used in FMMOs milk price determination procedure. In contrast, a statistically significant decrease in the average Exchange spot cheddar cheese price (while controlling for variation in milk price) is associated with the introduction of a multiple component pricing in 2000. The estimated pattern of cheese price behavior is consistent with the behavior of wholesale margin revealed by the descriptive statistical analysis (i.e. an increase in BFP regime and a decrease in MCP regime). The largest magnitude increase in the cheese price variance coincides with the second part of BFP regime when the frequency of spot cheese trade was changed from a weekly trade to a daily trade.

7. CONCLUSION

The changes in the design of FMMOs milk pricing during the analyzed milk pricing regimes indicate that the effects of the Exchange spot cheese market and spot cheese prices on FMMOs milk pricing have intensified. In a broader framework, the interaction between FMMOs, a key public pricing institution, and the Exchange spot cheese market, the industry private pricing institution performing a primary price discovery function in the U.S. dairy industry, has increased. Consequently, the relationship between the Exchange spot cheese price and Class III milk price has become much more complex in the most recent FMMOs regime. A significant increase in the volatility of Class III milk price and Exchange spot cheese prices in BFP and MCP regimes and similar patterns of changes in the level and volatility of these prices may reflect some of the effects of this interaction. In light of the recent concerns about the effects of CME spot cheese prices on FMMOs milk pricing and increasing milk price volatility and its effects on dairy farm profitability, the empirical results presented in this article may suggest the following.

First, there is empirical evidence indicating that the largest magnitude increase in the Exchange spot cheddar cheese price volatility took place during BFP regime, in particular during its second part, when a daily trading was introduced at CME, as opposed to a weekly trading at NCE. At the same time, during BFP regime the NCE spot cheddar block price was included in a formula used in the FMMOs milk price determination procedure. The increasing volatility of the Exchange spot cheese price, through the milk price formula, might have caused (or might have contributed to) the increasing volatility of Class III milk price, and consequently the increasing volatility of milk price received by dairy farmers (Figure 1). In 2000, when a multiple component pricing system was introduced, wholesale cheese price became the main determinant in a set of price formulas used in FMMOs milk price determination procedure. Given that FMMOs milk price announcements take place on a monthly basis, the volatility of the Exchange spot cheese price has a potential to cause (or to contribute to) the volatility of the Class III milk price and milk price received by dairy farmers on a monthly basis as well.

Second, while the volatility of the Exchange spot cheddar cheese prices and Class III milk price has increased dramatically, changes in the level of these prices were rather modest over the analyzed period of time. Given that the Exchange spot cheese market is concentrated, and there is a relatively small number of cheese sellers and buyers trading on a regular basis, the Exchange spot cheese prices are outcomes of the interaction of the Exchange sellers and buyers who have a potential to exercise market power on both the Exchange spot cheese market and contract cheese market. In addition, the firms who are cheese sellers and buyers at the Exchange spot cheese market in frequent instances may be competitors in the contract cheese market.

Given that the Exchange spot cheese prices are reference prices in cheese contracts used to transact more than 90% of cheese produced in the U.S., both the Exchange sellers and buyers might benefit from a lower level of the Exchange spot cheese price, in which case they have more control over the margin magnitude when they sell cheese at the wholesale and/or retail level. Apparently, the nature of the Exchange spot cheese price determination process, in light of the cheese industry alone, ensures a relatively low level of this price. However, in light of the overall dairy industry and the design of the modern FMMOs milk pricing system, a relatively low level of the Exchange spot cheddar cheese price might cause (or contribute to) a lower level of Class III milk price, the mover of the FMMOs pricing structure, and consequently to a lower level of milk price received by dairy farmers, which may have adverse effect on the dairy farm profitability.

There is a number of factors affecting that U.S. dairy industry pricing that might have contributed to the observed empirical patterns of the Exchange spot cheese price behavior. During the recent decade, the U.S. dairy industry increased its presence in international markets, when the U.S. dairy product prices started approaching dairy product prices in international markets (Brown et al., 2010). Therefore, the U.S. dairy industry has become more affected by price fluctuations transpiring from international markets. During the last few decades, significant structural changes, including increasing concentration and consolidation, took place in the U.S. dairy industry (Gould, 2010; Shields, 2010). This process has affected all segments of the dairy industry (fluid milk processing, cheese manufacturing, etc.). In particular, in the case of the cheese industry, a smaller number of sellers and buyers trade on the CME spot cheese market, as compared to NCE. A smaller number of industry participants have more market power, which the industry participants may use to influence prices.

In conclusion, a number of directions for future research should be suggested. First, there is a lack of studies focusing on the design of pricing systems used in modern cheese contracts. The cheese industry is complex and is heterogeneous in terms of the type of cheese buyers and sellers and pricing strategies used. Second, the empirical evidence presented in the article indicates that the Exchange spot cheese market reacted to changes in the FMMOs pricing regimes and the Exchange trading rules. Future research should focus on evaluating the nature of the Exchange spot cheese market reaction to these changes and the subsequent effects on the dairy industry conduct and performance. These studies would provide additional evidence on the conduct and performance of a primary price discovery institution in the U.S. dairy industry. Third, the issue of increasing volatility of the Exchange spot cheese prices and Class III milk price deserves a further econometric analysis. Finally, an analysis of the interaction of market power of cheese sellers and buyers at the CME spot cheese market and the effects that this interaction has on the CME spot cheese price behavior deserves consideration.

APPENDIX

Data Sources

1). U.S. Department of Agriculture Agricultural Marketing Service Dairy Market Statistics Annual Summaries. https://www.ams.usda.gov/market-news/dairy-market-statistics-annual-summaries

- The Exchange (NCE and CME) spot cheese market variables: spot price of cheddar cheese sold in 40 pound blocks, spot price of cheddar cheese sold in 500 pound barrels, actual sales, unfilled bids and uncovered offers.
- Cheddar cheese production and all cheese production.

2). U.S. Department of Agriculture Agricultural Marketing Service Milk Marketing Order Statistics Public Database. http://apps.ams.usda.gov/USDAMIB/Main/Welcome.aspx

- Class III milk price.
- Cheddar cheese price used in FMMOs price formulas.

U.S. Department of Agriculture National Agricultural Statistics Service Data and Statistics Database. https://www.nass.usda.gov/Quick_Stats/index.php

- All-milk price (milk price received by dairy farmers).

Regression Diagnostics

1). The spot cheese price and Class III milk price series are stationary series. In both cases the null hypothesis of a presence of the unit was rejected using a standard Dickey-Fuller unit root test for models with 1-10 lags. For example, the Dickey-Fuller test statistics for models with one lag are -5.30 and -4.92 for the spot cheese price and Class III milk price, respectively; both statistics exceed (in absolute value) the critical value of -2.75 (10% significance level). Furthermore, the correlograms of autocorrelation function (ACF) and partial autocorrelation function (PACF) indicate that autocorrelation substantially declines at the second lag value in the case of the spot cheese price series and Class III milk price series. This evidence supports the stationarity of the analyzed price series.

2). The ARCH test is used to test for the presence of autoregressive conditional heteroscedasticity (Hamilton, 1994; Kennedy, 2003). The ARCH test is based on the Lagrange multiplier principle. The LM statistic is $N*R2$, where N is the number of observations and $R2$ is a goodness-of-fit statistic from the regression of the squared residuals obtained from the OLS regression on a constant and m lagged values of the squared residuals. This statistic has an asymptotic Chi-square distribution with m degrees of freedom. The null hypothesis of homoscedasticity is rejected at a p-value equal to 0.0000 in the case of both estimated models (Table 4). This ARCH test outcome suggests that the ARCH model may be suitable for describing the error process.

3). To determine the order of the ARCH process, statistical significance of the estimated coefficients for squared error terms in the variance equation is evaluated. In the case of both models, only the estimated coefficient for the first lag of the squared error term is statistically significant. In addition, the Akaike and Schwarz information criteria (AIC and SC) are evaluated for the model specifications with different lag structures. Both AIC and SC are minimized when one lagged variable is in included in the variance equation. Therefore, ARCH(1) model is used in econometric analysis.

4). To determine the number of lagged milk price variables to be included in the conditional mean equation, statistical significance of the estimated coefficients for alternative number of lagged milk prices is evaluated. In the case of both models, only the estimated coefficients for the first and second lags are statistically significant. In addition, the Akaike and Schwarz information criteria (AIC and SC) are evaluated for the model specifications with different lag structures. Both AIC and SC are minimized when the first lag and the second lag of milk price are included in the conditional mean equation.

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<table>
<tr><th>FMMOs Milk Pricing Regime</th><th>Exchange Spot Cheese Market</th></tr>
<tr><td>Minnesota-Wisconsin price
1960s – May 1995</td><td rowspan="2">• Cheddar cheese sold in
40 pound blocks and 500 pound barrels
• Weekly trading
• Traders are present in person
• Identities of traders are known

National Cheese Exchange (NCE)
1974 – April 1997</td></tr>
<tr><td rowspan="2">Basic Formula Price
June 1995 – December 1999

<u>NCE period</u>: NCE spot price for cheddar sold in 40 pound blocks is used in a milk price formula.

<u>CME period</u>: Survey-based wholesale price (first-handler level) of cheddar sold in 40 pound blocks is used in a milk price formula.</td></tr>
<tr><td rowspan="2">May 1997 - present
Chicago Mercantile Exchange (CME)

• Cheddar cheese sold in
40 pound blocks and 500 pound barrels
• Daily trading
• Anonymous trading
• Professional brokers represent traders</td></tr>
<tr><td>Multiple Component Pricing
January 2000 - present

Survey-based wholesale cheddar cheese price (first-handler level) is used in milk price formulas. This price is based on price of cheddar sold in 40 pound blocks and price of cheddar sold in 500 pound barrels.</td></tr>
</table>

Chart 1 FMMOs Milk Pricing Regimes and the Exchange Spot Cheese Market.

TABLE 1. Wholesale Cheddar Cheese Prices: Chicago Mercantile Exchange and USDA National Agricultural Statistics Service (2000-2014).

Year	Wholesale cheddar cheese prices			
	Chicago Mercantile Exchange spot prices		USDA NASS survey-based prices used in FMMOs price formulas	
	barrel	block	barrel	block
	$/pound	$/pound	$/pound	$/pound
2000	1.1109	1.1465	1.0985	1.1332
2001	1.4052	1.4386	1.4039	1.4165
2002	1.1438	1.1822	1.1575	1.1808
2003	1.2703	1.3172	1.2771	1.297
2004	1.6036	1.6492	1.6216	1.6325
2005	1.4484	1.4928	1.4621	1.4821
2006	1.219	1.2385	1.2305	1.2318
2007	1.7411	1.7578	1.7267	1.7172
2008	1.8357	1.8558	1.8836	1.8801
2009	1.2518	1.2961	1.2734	1.2900
2010	1.4751	1.4964	1.5033	1.5138
2011	1.7870	1.8064	1.8146	1.8084
2012	1.6599	1.6980	1.6888	1.6972
2013	1.7165	1.7642	1.7456	1.7620
2014	2.0747	2.1094	2.1283	2.1341
Average	1.5162	1.5499	1.5344	1.5451

Data Source: USDA National Agricultural Statistics Service and Agricultural Marketing Service.

TABLE 2. The Exchange Spot Cheddar Cheese Market Trading Activities (1983-2015).

	Trading activities				Exchange cheddar sales as a percentage of the U.S. production (%)	
	Actual sales	Unfilled bids	Uncovered offers	Total trading activity		
	Carloads* (% in total trading activity)				Cheddar	All cheese
Minnesota-Wisconsin price regime (active DPPSP: January 1983 – December 1989)						
Average**	346 (56)	93 (19)	153 (25)	592 (100)	0.65	0.28
[Min; Max]	[29; 754]	[5; 281]	[4; 287]	[38; 1086]	[0.05; 1.41]	[0.03; 0.61]
Minnesota-Wisconsin price regime (inactive DPPSP: January 1990 – December 1994)						
Average	503 (63)	158 (22)	120 (15)	781 (100)	0.90	0.33
[Min; Max]	[342; 799]	[126; 194]	[72; 176]	[569; 1061]	[0.60; 1.43]	[0.24; 0.50]
Basic Formula Price regime (January 1995 – December 1999)						
Average	1,296 (69)	288 (13)	449 (18)	2,033 (100)	2.08	0.74
[Min; Max]	[1,104; 1,544]	[56; 635]	[105; 1,270]	[1,381; 3,449]	[1.76; 2.31]	[0.62; 0.82]
Multiple Component Pricing regime (January 2000 – December 2015)						
Average	976 (56)	404 (23)	385 (21)	1,765 (100)	1.33	0.42
[Min; Max]	[533; 1,724]	[141; 1,011]	[161; 1,306]	[1,116; 2,706]	[0.72; 2.26]	[0.24; 0.72]

* One carload contains 40,000-44,000 pounds of cheese. To calculate the percentages, the number of carloads is converted into pounds by assuming that one carload contains 42,000 pounds of cheese. The percentages are calculated by the author using cheese production data reported by the USDA Agricultural Marketing Service.

** Yearly data are used to generate results reported in the table. Cheddar block and cheddar barrel are combined.

TABLE 3. The Exchange Spot Cheddar Cheese Prices, Class III Milk Price and Wholesale Margins (1983-2015).

	Exchange cheddar cheese price, $/pound		Class III milk price, $/cwt	Wholesale margin, % of cheddar cheese price	
	Barrel	Block		Barrel	Block
Minnesota-Wisconsin price regime (01/1983-12/1989: active DPPSP)					
Average	1.24	1.28	11.74	5.32	8.49
CV**	0.07	0.07	0.07	0.42	0.23
Minnesota-Wisconsin price regime (01/1990-05/1995: inactive DPPSP)					
Average	1.24	1.27	11.76	5.17	7.55
CV	0.08	0.08	0.08	0.47	0.27
Basic Formula Price regime (06/1995-12/1999)					
Average	1.37	1.43	12.90	5.86	9.51
CV	0.13	0.13	0.14	0.93	0.47
Multiple Component Pricing regime (01/2000-12/2015)					
Average	1.52	1.55	14.94	2.44	4.62
CV	0.21	0.20	0.25	3.32	1.78

*To calculate wholesale margin, milk price is divided by 10 represent the cost of milk required to produce one pound of cheese.
**CV is the coefficient of variation; it is the ratio of standard deviation to the mean.
Monthly prices are used to generate results reported in the table.

TABLE 4. The Exchange Spot Cheese Price Behavior: ARCH(1) Models Estimation Results.

Variable	Model 1	Model 2
	Est. Coef. (T-ratio)	Est. Coef. (T-ratio)
Mean equation: Dependent variable is Exchange spot cheddar cheese price ($/lb.)		
MP_{t-1}	0.98* (7.36)	0.97* (13.07)
MP_{t-2}	-0.36* (-2.84)	-0.28* (-3.66)
$BFPWT_t$	0.05* (2.71)	0.04* (2.68)
$BFPDT_t$	0.12* (2.33)	0.10* (1.74)
MCP_t	0.03[a] (1.56)	0.06* (3.99)
$M2_t$ (February)	-0.01 (-0.59)	0.03 (0.99)
$M3_t$ (March)	0.05* (1.85)	0.06* (2.06)
$M4_t$ (April)	0.05* (1.79)	0.06* (2.02)
$M5_t$ (May)	0.05[a] (1.47)	0.06* (1.85)
$M6_t$ (June)	0.08* (2.75)	0.09* (2.85)
$M7_t$ (July)	0.12* (3.47)	0.09* (2.96)
$M8_t$ (August)	0.12* (4.09)	0.12* (4.18)
$M9_t$ (September)	0.11* (3.78)	0.12* (4.01)
$M10_t$ (October)	0.01 (0.22)	0.05[a] (1.46)
$M11_t$ (November)	0.00 (0.14)	0.04[a] (1.35)
$M12_t$ (December)	0.05[a] (1.43)	0.02 (0.83)
Constant	0.48* (5.95)	0.39* (9.27)
R2	0.70	0.81
D-W Statistic[1]	1.45	1.33
ARCH test *Chi-Square* (p-value)	20.33 (0.0000)	21.19 (0.0000)
Ho: BFPDT = BFPWT *T-St.*[2]	1.36[a]	1.00
Ho: MCP = BFPDT *T-St.*[2]	-1.61[b]	-0.69
Ho: MCP = BFPWT *T-St.*[2]	-0.59	0.97
Ho: CPT (MP_{t-1}) = 1 *T-St.*[3]	-0.15	-0.34
Ho: CPT (MP_{t-1}+ MP_{t-2}) = 0.5 *T-St.*[4]	1.70[a]	5.86[a]
Ho: CPT (MP_{t-1}+ MP_{t-2}) = 1 *T-St.*[4]	-5.47[b]	-9.49[b]
Variance equation: Dependent variable is conditional spot cheddar cheese price variance		
u_{t-1}^2	0.031 (0.40)	0.143* (2.84)
$BFPWT_t$	0.003 (1.04)	0.003 (0.48)
$BFPDT_t$	0.033* (6.99)	0.033* (3.75)
MCP_t	0.007* (2.56)	0.017* (4.65)
Constant	0.003[a] (1.63)	0.002 (0.75)
R2	0.33	0.12
D-W Statistic	2.04	2.02
Ho: BFPDT = BFPWT *T-St.*[2]	6.26[a]	3.07[a]
Ho: MCP = BFPDT *T-St.*[2]	-5.73[b]	-1.84[b]
Ho: MCP = BFPWT *T-St.*[2]	1.33[a]	2.50[a]

Table 4 (cont.).

[*] The estimated coefficient is statistically significant at the 10% significant level using a two-tailed T-test: Ha: β=0, Ha: β≠0; the T statistic rejection regions are (-∞; -1.64] and [1.64; +∞).
[a] The estimated coefficient is statistically significant at the 10% significance level using a one-tailed T test: Ha: β=0, Ha: β>0; the T statistic rejection region is [1.28; +∞).
[b] The estimated coefficient is statistically significant at the 10% significance level using a one-tailed T test: Ha: β=0, Ha: β<0; the T statistic rejection region is [-1.28; +∞).
[1] In the case of both models, T-ratios in the conditional mean equation are calculated using autocorrelation-adjusted standard errors based on Newey-West approach.
[2] A T-test on the change in the cheese price level (variance) between individual regimes/periods. The cell entry is the T-ratio. The null hypotheses are stated in the table. One-tailed T-test (as described above) is used to conclude on the test outcome in the case of each hypothesis. For example, Ho: BFPDT = BFPWT is the same as BFPDT – BFPWT = 0, and the corresponding Ha is BFPDT – BFPWT > 0.
[3] A T-test on the cost-pass through (CPT) magnitude (the current month milk price effect). The cell entry is the T-ratio. Ho CPT = 1 (a perfectly competitive pricing) and Ha CPT <1 (oligopoly pricing, linear demand). One-tailed T-test (as described above) is used to conclude on the test outcome.
[4] A T-test on the cost-pass through (CPT) magnitude (the cumulative effect of the current month and previous month milk price). The cell entry is the T-ratio. (a) Ho CPT = 0.5 (monopoly pricing, linear demand) and Ha CPT > 0.5 (oligopoly pricing, linear demand). (b) Ho CPT = 1 (a perfectly competitive pricing) and Ha CPT < 1 (oligopoly pricing, linear demand). One-tailed T-test (as described above) is used to conclude on the test outcome.
Number of observations: 167 observations in Model 1 and 396 observations in Model 2.

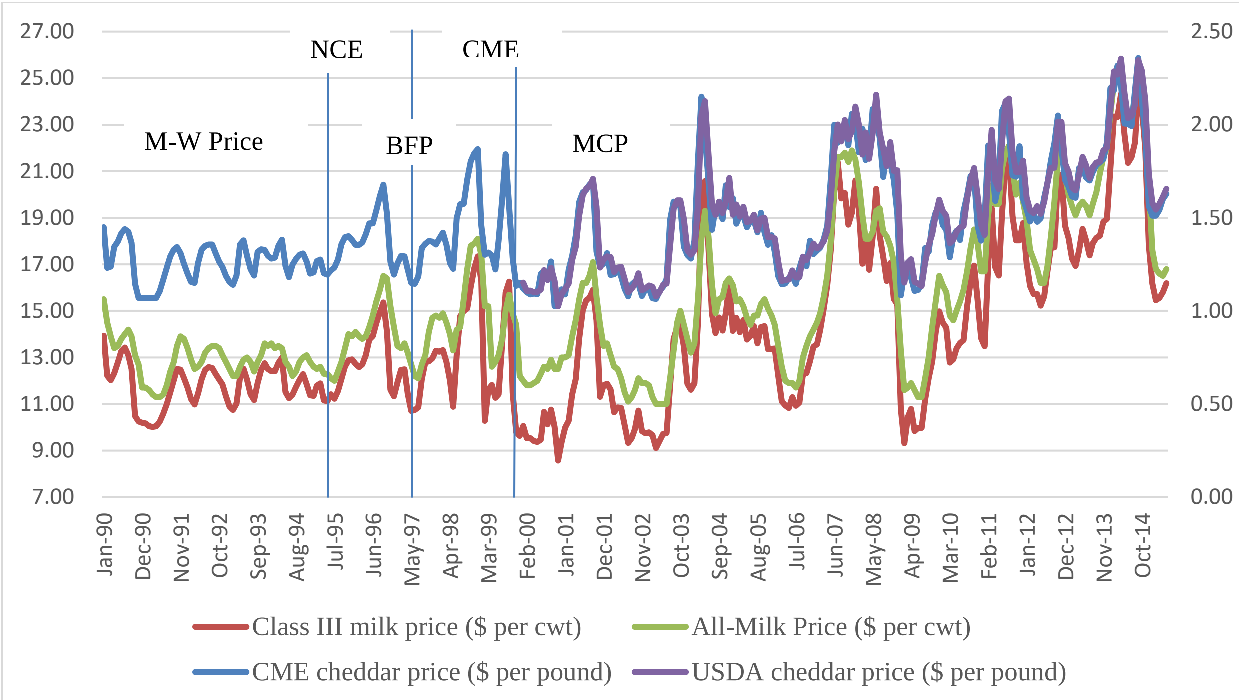

Figure 1 U.S. Dairy Industry: Cheddar Cheese Prices and Milk Prices (January 1990 – May 2015).

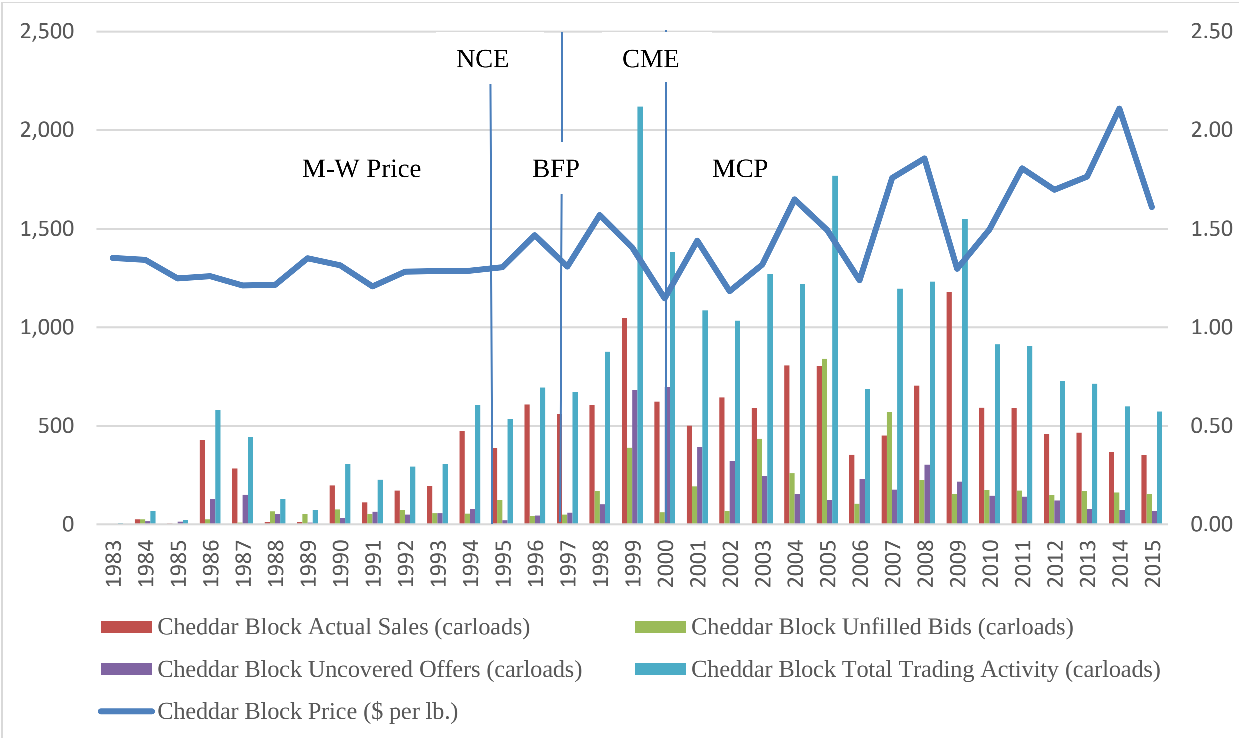

Figure 2 The Exchange Spot Cheese Market Trading Activities:
Cheddar Cheese Sold in 40 pound Blocks (January 1993 – December 2015).