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## **An Empirical Analysis of Wholesale Cheese Pricing Practices on the Chicago Mercantile Exchange (CME) Spot Cheese Market**

Yuliya V. Bolotova<sup>Ⓐ</sup> and Andrew M. Novakovic<sup>Ⓑ</sup>

<sup>Ⓐ</sup> *Assistant Professor of Agribusiness, Department of Agricultural and Environmental Sciences, Clemson University, 237 McAdams Hall, Clemson, South Carolina, 29634-0310, USA*

<sup>Ⓑ</sup> *E.V. Baker Professor of Agricultural Economics, Charles H. Dyson School of Applied Economics and Management, Cornell University, 451A Warren Hall, Ithaca, New York, 14853-7801, USA*

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### **Abstract**

The CME spot cheese market performs a number of key functions in the United States dairy industry. The CME spot cheese prices are used as reference prices in contract cheese market, and they also influence milk prices at the farm-first-handler level set within a public pricing system, the Federal and State Milk Marketing Orders. The CME spot cheese market performs a critical price-discovery function in the United States dairy industry. This research evaluates the nature of pricing practices used by CME cheese wholesalers during the period of 2000-2014. The analysis focuses on the farm-to-wholesale price transmission process, which reflects the nature of cost pass-through. The empirical evidence presented in the article indicates that pricing strategies of cheese sellers in the analyzed market are consistent with the ones predicted by the profit-maximization models of oligopolistic behavior. The overall empirical evidence may suggest that cheese sellers on the CME spot cheese market used an output (cheese) price stabilization method during the analyzed period of time.

**Keywords:** asymmetric price transmission, cheese industry, Chicago Mercantile Exchange, cost pass-through, dairy industry, Federal Milk Marketing Orders, oligopoly, price regulation, price stabilization practice, spot market, supply chain management, thin market

<sup>Ⓐ</sup>Corresponding author: Tel: + 1.864.656 4079

Email: Y. V. Bolotova: yuliyab@clemson.edu

A. M. Novakovic: a.novakovic@cornell.edu

## Introduction

The Chicago Mercantile Exchange (CME) spot cheese market performs a number of key functions in the United States dairy industry. First, the CME spot cheese prices are used as reference prices in cheese contracts used to transact more than 90% of cheese manufactured in the country. Second, the CME spot cheese prices influence milk prices set within the Federal and State Milk Marketing Orders (a public pricing system)<sup>1</sup>. The analyzed spot cheese market (which currently functions on the Chicago Mercantile Exchange) is a private industry institution. It was organized at the beginning of the last century with the original purpose of trading surpluses of cheese. Over time, this market became an institution performing a primary price discovery function in the United States dairy industry<sup>2</sup>.

The CME spot cheese market is a low volume market in which a relatively small number of traders regularly participate. Typically less than 1% of the total volume of cheese produced in the country is traded on it (Table 1; GAO report 2007). Its major participants are large cheese/food processing companies and large agricultural cooperatives manufacturing cheese, who also operate in the contract cheese market. In light of the role that the Exchange spot cheese market plays for milk as well as cheese price discovery in the modern dairy industry, these market characteristics have raised concerns about occasional market manipulations allegedly taking place on this market (Mueller et al. 1996, Mueller et al. 1997, Mueller and Marion 2000, GAO report 2007, U.S. Departments of Agriculture and Justice 2010a,b, Carstensen 2010, Gould 2010).

Despite a significant role that the CME spot cheese market performs in the modern dairy industry, research examining pricing issues relevant to this market is practically absent. To the best of our knowledge, only one systematic research project was undertaken, and it was during the time when the spot cheese trade took place on the National Cheese Exchange (NCE) prior to being moved to the CME. Mueller et al. (1996, 1997) and Mueller and Marion (2000) conducted an extensive empirical analysis of the conduct on the NCE and its performance during the period of 1988-1993, when the issue of susceptibility of this market to price manipulations was raised<sup>3</sup>.

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<sup>1</sup> Almost all raw milk produced in the U.S. is marketed within the system of Federal and State Milk Marketing Orders, which use a classified milk pricing principle to set the minimum prices paid for milk at the farm-first-handler level.

<sup>2</sup> In this article, "CME" and "Exchange" are used interchangeably. The predecessors of the CME spot cheese market are Wisconsin Cheese Exchange (Plymouth, WI) and National Cheese Exchange (Green Bay, WI). For a historical overview of cheese exchanges see Hamm and March (1995), Mueller et al. (1996) and Manchester and Blayney (1997). Despite the change of the physical location of the spot cheese market, the main participants and trading rules remained practically the same.

<sup>3</sup> There is research analyzing pricing issues in the overall cheese industry. For example, Chavas and Kim (2004, 2005) evaluated the effects of the price support program on price dynamics and price volatility in the U.S. cheese industry. Franklin and Cotterill (1994), Cotterill and Samson (2002) and Kim and Cotterill (2008) examined pricing issues in the national branded cheese industry. Kinnucan and Forker (1987), Awokuse and Wang (2009) and Stewart and Blayney (2011) analyzed asymmetries in price transmission process at the farm-to-retail and wholesale-to-retail levels of the cheese industry.

The objective of this research is to analyze the nature of wholesale cheese pricing practices used by cheese wholesalers on the CME spot cheese market. To accomplish this objective, the research proceeds as follows. First, we analyze the vertical milk price transmission process, which reflects the nature of cost pass-through for cheese wholesalers. Milk is the main input used to produce cheese, and the share of milk cost in the wholesale cheese price is approximately 90-95%. The estimated magnitude of cost pass-through can be used to distinguish between a perfectly competitive pricing and an imperfectly competitive pricing and to identify a pricing method used by cheese wholesalers.

Second, we use an econometric framework, which allows to analyze asymmetries in the milk price transmission process. Using this framework, we can identify whether these asymmetries exist and analyze their nature. In particular, we evaluate the CME wholesale cheese price response to increases and decreases in farm-level milk price. Third, using the cost pass-through estimates we calculate milk price transmission elasticities. The econometric analysis is based on publicly available data reported by the U.S. Department of Agriculture. The period of analysis is January 2000 – December 2014.

The article is organized as follows. First, a discussion of the CME spot cheese market structural characteristics and of its role in the dairy industry pricing is presented. Next, a traditional theoretical framework used to analyze the mechanism of vertical price transmission is discussed and is used to develop an econometric model to be estimated. The following sections discuss data and estimation results. The major findings of the analysis are summarized in the conclusion.

## **Chicago Mercantile Exchange (CME) Spot Cheese Market**

The CME (“Exchange”) spot cheese market is a low volume market and is concentrated. Only one variety of cheese, cheddar cheese, is traded on the Exchange. It is sold in 40 pound blocks and 500 pound barrels. The first, block cheddar, is of a type and packaging that is consistent with food manufacturing, food service, and retail uses of cheddar cheese. The second, barrel cheddar, is of a quality and cost that is oriented towards the production of processed cheese, which is especially important in food services. During the period of 2000-2013, less than 2% of the total cheddar cheese volume produced in the country was sold on the Exchange, which represented less than 1% of the total cheese production (Table 1).

Although there are 30-40 members in this market, only a small number of buyers and sellers actively trade on the Exchange (GAO report 2007). These are large cheese/food manufacturers and large agricultural cooperatives. The buyers and sellers trading on the CME are also active participants in the contract cheese market. As reported by GAO (2007), 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. Four market participants bought 56% of all barrel cheese and two market participants sold 68% of all barrel cheese. In addition to the low relative volume of trade, transactions are infrequent.

The CME spot cheese market structural characteristics are similar to the ones typically associated with imperfectly competitive market structures: a high degree of product homogeneity, inelastic short-run demand/supply, a relatively small number of traders (i.e. high

market concentration) and a relatively high barriers to entry. Cheddar cheese traded on the CME is a highly standardized product with inelastic short-run demand and supply, there are relatively few large market participants and a group of smaller firms, the entry is relatively limited because it requires a potential entrant to be able to buy or sell very large quantities of cheese on the spot (Mueller et al. 1996, Mueller et al. 1997).

In addition, some market participants may have incentives to influence the CME spot cheese prices in order to control the contract cheese market, where more than 90% of cheese is sold, and/or to influence prices of milk used in cheese manufacturing. Cheese pricing strategies in the contract market typically depend on the type of buyers. At the first handler level, contract prices are based on the Exchange spot cheese price on the day of cheese production plus or minus a premium (Hayenga 1979, Manchester and Blayney 1997). According to milk price formulas used to price milk within the Federal Milk Marketing Orders since 2000, manufacturing milk price (Class III milk price) is a function of a survey-based wholesale cheese prices collected by the U.S. Department of Agriculture<sup>4</sup>. The latter are at approximately the same level as the CME spot cheese prices (Table 1) and are highly correlated with these prices (GAO report 2007).

Cheese processors who buy cheese to manufacture processed cheese products would benefit from lower CME spot cheese prices. However, the net benefits would depend on the design of pricing systems used in cheese contracts. Agricultural cooperatives involved in cheese manufacturing would benefit from higher CME spot cheese prices because this would lead to higher prices paid for milk. Given the CME spot cheese market structural characteristics and potential incentives of its participants, we hypothesize that pricing practices used by cheese wholesalers are consistent with an imperfectly competitive pricing rather than with a perfectly competitive pricing.

## Theoretical Framework

### *Vertical Price Transmission*

An economic model of vertical price transmission is used as a theoretical framework for empirical analysis of wholesale cheese pricing practices. The vertical price transmission mechanism characterizes the process of reaction of output prices to changes in input prices. A considerable number of studies focusing on vertical price transmission in agricultural and food industries explored asymmetries in the transmission of changes in input prices to output prices, which is common in these industries. The nature of vertical price transmission characterizes market efficiency and performance. Also, the vertical price transmission mechanism reflects cost pass-through, which can be used to characterize pricing practices used by the food supply chain participants (i.e. wholesalers and retailers).

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<sup>4</sup> Within the system of Federal Milk Marketing Orders, there are four classes of milk that are based on four different final uses of raw milk. Class I milk is used to produce fluid beverage milk products, Class II milk is used to manufacture “soft” dairy products (yogurt, cottage cheese, ice cream, etc.), Class III milk is used to manufacture “hard” dairy products (cheese and cream cheese), and Class IV milk is used to produce butter and dry milk. Class III milk price is the “mover” of the overall FMMOs pricing structure.

The mechanism of vertical price transmission has been a focus of many theoretical and empirical studies. Some studies developed theoretical models without applying them to a particular industry setting (Azzam 1999, McCorriston et al. 2001, Weldegebriel 2004). The hypotheses developed in these studies provide a valuable guidance for future empirical work. Some studies focused on time-series econometric analysis to test hypotheses in the setting of a specific industry, which provides insights on how this industry performs (Kinnucan and Forker 1987, Lass et al. 2001, Lass 2005, Carman and Sexton 2005, Capps and Sherwell 2007, Awokuse and Wang 2009, Stewart and Blayney 2011)<sup>5</sup>.

There is no unique research methodology used to analyze vertical price transmission. The core of any model, whether simple or complex, theoretical or empirical, is that output (downstream) price is modeled as a function of input (upstream) price. In the setting of agricultural and food industries, the output price is typically represented by either retail or wholesale price, in which case the input price is represented by wholesale and/or farm price.

We use a theoretical framework adopted in earlier empirical studies focusing on farm-to-retail price transmission and retail pricing practices in the U.S. fluid milk industry (Carman and Sexton 2005, Bolotova and Novakovic 2012). This theoretical framework includes re-arranged versions of standard profit-maximizing first-order conditions for a perfectly competitive industry, monopoly and oligopoly. These conditions represent pricing rules and are derived using classic static models of profit-maximizing behavior, in which firms set output quantity to maximize their profit (i.e. the Cournot model in the case of oligopoly); other assumptions include an assumption on demand (linear or non-linear) and a constant marginal cost (Besanko and Braeutigam 2002, Carlton and Perloff 2005).

#### *CME Spot Cheese Market: Vertical Price Transmission Mechanism and Hypotheses*

Equation (1) represents a linear farm-to-wholesale price transmission process. The price of output (downstream price) is specified as a linear function of the input price (upstream price).

$$(1) \quad WP = a + b*FP.$$

In the setting of our research, *WP* is the CME wholesale cheddar cheese price (“cheese price” to be referred further in the article)<sup>6</sup>, *FP* is a farm-level price of milk used in cheese manufacturing (“milk price” to be referred further in the article), *a* is a non-negative constant, and *b* is a farm price transmission coefficient (i.e. a cost pass-through).

Milk represents about 90% of the cost of bulk cheese manufacturing. The farm price in equation (1) is represented by the Class III milk price. This is a government-set minimum price that milk processors have to pay for milk used in cheese manufacturing within the system of Federal Milk Marketing Orders. Dairy farmers do not receive this price directly. Rather they receive a price

<sup>5</sup> For comprehensive surveys of these studies, see Meyer and von Cramon-Taubadel (2004) and Frey and Manera (2007).

<sup>6</sup> “Wholesale cheese price” and “spot cheese price” are used interchangeably throughout the article. Similarly, “wholesale cheese market” and “spot cheese market” are used interchangeably.

related to the weighted average of all milk class prices, called the Uniform or blend price. As such, the Class III milk price is not a “farm price” in the conventional sense of what is paid to the farmer, but it is the transaction price relevant to the farmer-first-handler level of the supply chain.

The Class III milk price is announced by the 5<sup>th</sup> of the month following the month in which this price applies. Therefore, during the current month only the previous month Class III milk price is known. The flow of the causation effect from the previous month Class III milk price ( $FP$ ) to the current month CME spot cheese price ( $WP$ ) is ensured in the cheese industry institutional environment.

Given that wholesale margin is the difference between wholesale price and farm price:

$$(2) \quad WM = WP - FP,$$

substituting (1) into (2) yields the identity for wholesale margin:

$$(3) \quad WM = a + (b-1)*FP.$$

The magnitude of the coefficients in equations (1) and (3) provides evidence on the pricing method used by wholesalers. The magnitude of  $b=1$  and  $a>0$  would reflect a fixed absolute markup pricing consistent with perfect competition characterized by a “sticky” margin ( $WM=a$ ). In the case of imperfectly competitive pricing, two special cases can be considered ( $b<1$  and  $b>1$ ).

If a profit-maximizing monopolist operates in a market environment with linear demand and constant marginal cost, the magnitude of  $b$  is equal to 0.5 (i.e. incomplete cost pass-through). The first-order profit-maximization condition for this monopolist can be rearranged to express its output price as a function of marginal cost:  $P = 0.5 + 0.5*MC$ . The constant  $a$  is non-negative in this case. A profit-maximizing oligopoly in a similar market environment would yield the magnitude of  $b$  in the range from 0.5 (monopoly) to 1 (perfect competition). The output price stabilization practice would be consistent with pricing predicted by these models.

In the case of a profit-maximizing monopoly and a profit-maximizing oligopoly operating in a market environment with non-linear demand and constant marginal cost, the magnitude of  $b$  is greater than 1 (i.e. more than a complete cost pass-through). The oligopoly cost pass-through is greater than one and is smaller than the monopoly cost pass-through. The first-order profit-maximization conditions (FOC) for monopoly and oligopoly are:

$$P = \left( \frac{1}{1 + \frac{1}{\eta}} \right) \times MC \quad \text{and} \quad P = \left( \frac{1}{1 + \frac{1}{N \times \eta}} \right) \times MC, \quad \text{respectively} \quad (\eta_{Q,P} = \frac{dQ}{dP} \times \frac{P}{Q} < 0 \text{ is the market}$$

demand elasticity, and  $N$  is the number of firms in the case of oligopoly). The constant  $a$  is zero in these models. The terms in the parentheses (i.e. cost pass-through) must

be greater than one for the output price to exceed marginal cost<sup>7</sup>. Introducing  $N$  in the FOC for oligopoly decreases the magnitude of cost pass-through, as compared to the monopoly case. The fixed percentage markup pricing (George and King 1971, Carman and Sexton 2005, Bolotova and Novakovic 2012) is consistent with pricing predicted by these models; this pricing method reflects the margin stabilization strategy.

The behavior of wholesale margin is conditional on the magnitude of cost pass-through. If  $b=1$  (a perfect competition case), wholesale margin is constant:  $WM=a$  in equation (3); the margin does not respond to the changes in the farm price in this case. If  $b>1$  or  $b<1$  (an imperfect competition case), wholesale margin responds to the changes in the farm price. In the case of incomplete cost pass-through ( $b<1$ ), wholesale margin decreases (increases), given a farm price increase (decrease). In the case of more than a complete cost pass-through ( $b>1$ ), wholesale margin increases (decreases), given a farm price increase (decrease). Therefore, the margin response to the same change in the farm price is different under the two presented scenarios of imperfectly competitive pricing.

## Econometric Framework

### *Econometric Models of Asymmetric Price Transmission: The Overview*

There is a wide variety of econometric models that can be used to analyze asymmetry in the price transmission process. In their comprehensive survey of econometric models of asymmetric price transmission, Frey and Manera (2007) distinguish nine types of econometric models, and the total of fifteen modifications of these models (Frey and Manera 2007: Table 5). The most common econometric models include autoregressive distributed lag models (ARDL), error correction models (ECM), regime switching model (RSM), vector error correction model (VECM) and vector autoregressive models (VAR). Meyer and von Cramon-Taubadel (2004) is another survey of econometric models used to analyze asymmetric price transmission. They classify the analyzed models into the pre-integration approaches to testing for asymmetric price transmission (ARDL is an example) and cointegration analysis (ECM is an example). The ECM and cointegration assume that the long-run equilibrium exists between the output price and input price, which precludes these prices to drift apart (Meyer and von Cramon-Taubadel 2004). If this is true for the analyzed data, then ECM may be superior to other econometric models.

The choice of the econometric model for a particular study typically depends on the time-series properties of the analyzed data. A standard approach is to conduct an appropriate statistical test to check on the stationarity of the output and input prices, which relationship is analyzed. If the price series was found to be nonstationary (may indicate the need for ECM), the second step is to check for cointegration<sup>8</sup>. Capps and Sherwell (2007) analyzed the performance of a traditional Houck model (a variation of ARDL) and ECM in the case of U.S. fluid milk industry. Based on the empirical evidence reported for a number of U.S. cities and fluid milk products (whole milk

<sup>7</sup> The cost pass-through is greater than one, if the absolute value of market demand elasticity is greater than one (i.e. monopolist and oligopolists price on the elastic region of market demand curve, in which case marginal revenue is positive).

<sup>8</sup> A comprehensive explanation of the available statistical tests and procedures is presented in Kennedy (2003).

and reduced fat milk), it was concluded that the Houck approach and ECM were statistically indistinguishable.

The Houck approach has been widely used to analyze asymmetries in the vertical price transmission process in the U.S. dairy industry (Kinnucan and Forker 1987, Lass et al. 2001, Lass 2005, Carman and Sexton 2005, Capps and Sherwell 2007, Bolotova and Novakovic 2012). The two studies that applied ECMs are Awokuse and Wang (2009) and Stewart and Blayney (2011). Some of the estimated econometric models reported for the cheese industry in the latter studies have a low level of explanatory power and some of the coefficients lack statistical significance. The institutional environment of the U.S. dairy industry includes regulated pricing at the farm level, which may affect the nature of farm-to-retail price transmission process in the U.S. dairy industry and the performance of econometric models. The milk prices at the farm-first-handler level are calculated by the government and publicly announced on a monthly basis. This affects the pricing strategies of wholesalers and retailers, who are likely to adjust their pricing decisions on a monthly basis as well, following the government price announcement at the farm level.

#### *CME Spot Cheese Market: Econometric Model of Vertical Price Transmission*

Following the majority of previous empirical studies focusing on the U.S. dairy industry, we use the Houck approach to specify an econometric model. As indicated by the results of statistical tests reported later in the article, the cheese and milk prices used in the empirical analysis are stationary. Therefore, we do not explore the possibility of using an error correction model.

Equation (1) is used as a base to specify an econometric model to be estimated. In this equation, the cost pass-through is restricted to be invariant to increases and decreases in the farm price. To allow for asymmetric adjustment of the CME wholesale cheese price to increases and decreases in a farm milk price (i.e. Class III milk price), we incorporate the Houck (1977) procedure to specifying and estimating nonreversible functions into wholesale price equation (1). The Houck approach is based on segmenting an independent variable of interest into its increasing and decreasing phases in order to explore asymmetries in the adjustment of the dependent variable to increases and decreases in the independent variable. Equation (4) represents a general version of the Houck model.

$$(4) Y_t^* = a_0 \times t + a_1 \times INC_t^* + a_2 \times DEC_t^*,$$

where  $Y_t^*$  is the sum of all period-to-period changes in the dependent variable from its initial value,  $INC_t^*$  is the sum of all period-to-period increases and  $DEC_t^*$  is the sum of all period-to-period decreases in the independent variable from its initial value.  $INC_t^*$  is always positive, and  $DEC_t^*$  is always negative. If  $a_0$  is non-zero, then it appears as a trend coefficient.

The Houck procedure was originally developed as a static model. In many applications, corresponding econometric models were specified with distributed lag structures to account for dynamic effects. This approach allows the researcher to analyze asymmetries in terms of both the magnitude and speed of price transmission.



By combining equations (1) and (4), we specify an econometric model to be estimated, which is represented by equation (5). This is a linear distributed lag model.

$$(5) WP_t^* = \alpha_0 \times t + \sum_{i=0}^N \beta_i^+ \times FP\_INC_{t-i}^* + \sum_{i=0}^M \beta_i^- \times FP\_DEC_{t-i}^* + u_t.$$

The majority of the notations used in equation (5) are as explained above.  $N$  and  $M$  are the number of lagged terms for increasing and decreasing phases of milk price, respectively. Due to the specifics of the Class III milk price announcement procedure mentioned earlier, the previous month Class III milk price is used as the current month  $FP$  in the econometric model.  $\beta_i^+$  and  $\beta_i^-$  are the milk price transmission coefficients (i.e. cost pass-through) for increasing and decreasing phases of milk price, respectively.  $u_t$  is the error term.

The null hypothesis of the symmetry in terms of the speed<sup>9</sup> of the cheese price adjustment to increases and decreases in milk price would be supported if  $N=M$ . The null hypothesis of the symmetry in terms of the magnitude of the cheese price adjustment would be supported if  $\beta_0^+ = \beta_0^-$  (for the current month effect) and  $\sum_{i=0}^N \beta_i^+ = \sum_{i=0}^M \beta_i^-$  (for the cumulative effect).

Furthermore, the magnitude of the estimated cost pass-through is to be interpreted in light of the discussion presented in the previous section. The empirical evidence supporting a perfectly competitive pricing would include the magnitude of cost pass-through equal to one and a symmetric adjustment of the cheese price to increases and decreases in milk price. The empirical evidence on the magnitude of cost pass-through statistically smaller or greater than one and a presence of asymmetries in the cheese price response would indicate a presence of imperfectly competitive pricing.

The estimated coefficients from equation (5) can be used to calculate the price transmission elasticities (Kinnucan and Forker 1987, Lass et al. 2001, Capps and Sherwell 2007, Bolotova and Novakovic 2012). The elasticities calculated based on the current month effect of milk price change are:  $e_{INC} = \beta_0^+ \times \frac{\overline{FP}_t}{\overline{WP}_t}$  (the milk price-increase transmission elasticity) and  $e_{DEC} = \beta_0^- \times \frac{\overline{FP}_t}{\overline{WP}_t}$

(the milk price-decrease transmission elasticity), where  $\overline{FP}_t$  and  $\overline{WP}_t$  are sample means for the milk price series and the CME wholesale cheese price series, respectively. Similarly, the elasticities of cumulative effects of the milk price changes<sup>10</sup> are  $e_{INC} = \sum_{i=0}^N \beta_i^+ \times \frac{\overline{FP}_t}{\overline{WP}_t}$  and

$$e_{DEC} = \sum_{i=0}^M \beta_i^- \times \frac{\overline{FP}_t}{\overline{WP}_t}.$$

<sup>9</sup> See Meyer and von Cramon-Taubadel (2004) for a discussion of different types of asymmetry in the price adjustment process (i.e. in terms of speed, magnitude, etc.).

<sup>10</sup> The price transmission elasticity calculated based on the current month effect of the farm price change is often referred to as the short-run price-transmission elasticity, and the one calculated based on the cumulative effect of the farm price changes is referred to as the long-run price-transmission elasticity (Kinnucan and Forker 1987, Capps and

The magnitude of price transmission elasticities can be interpreted conditional on the magnitude of cost pass-through. The price transmission elasticity in a perfectly competitive market is equal to the ratio of the farm price to the wholesale price, because the cost pass-through is equal to one in this case. The elasticity corresponding to an oligopolistic/monopolistic market with linear demand is smaller than the ratio of the farm price to the wholesale price, and the elasticity characterizing an oligopolistic/monopolistic market with non-linear demand is greater than this ratio. This is because the cost pass-through is smaller than one in the former case and is greater than one in the latter case.

## Data

The variables used in econometric analysis are collected from the data bases maintained by the U.S. Department of Agriculture Agricultural Marketing Service (USDA AMS). CME cheddar cheese prices are reported by the USDA AMS Dairy Market News Portal and are represented by two price series: cheddar prices for 500 pound barrels and cheddar prices for 40 pound blocks. CME cheddar cheese prices are originally reported on a daily basis, but they are also available on a weekly and a monthly basis. Class III milk prices are reported in the USDA AMS Milk Marketing Order Statistics Public Database. Class III milk price is determined and announced (reported) on a monthly basis. The econometric model is estimated using monthly data, the frequency at which both cheese and milk prices are available. The period of analysis is January 2000 – December 2014.

CME cheddar cheese prices are reported in \$/pound, and Class III milk price is reported in \$/cwt<sup>11</sup>. As a general rule, about 10 pounds of milk yields 1 pound of cheese. Therefore, instead of using milk price expressed in \$/cwt in the econometric models, we use a yield adjusted measure of the cost of milk incurred to produce one pound of cheese. This variable is obtained by dividing milk price expressed in \$/cwt by 10. This simple transformation allows for easier interpretation of the parameter estimates.

## Estimation Results

Two econometric models were estimated. One model used the CME cheddar barrel price as the dependent variable, and the other model used the CME cheddar block price as the dependent variable<sup>12</sup>. The Ordinary Least Squares (OLS) estimation procedure was used to estimate econometric models. The estimation results of the two models were very similar. Given that cheddar block has a wider variety of uses than cheddar barrel and is also directly used in final consumption, we present and discuss the estimation results for the model which has the CME

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Sherwell 2007). Lass et al. (2001) use a different terminology: a former is referred to as the current elasticity, and the latter is referred to as the short-run elasticity.

<sup>11</sup> One cwt (hundredweight) contains 100 pounds.

<sup>12</sup> The cheddar cheese (block and barrel) and milk price series were tested for a presence of the unit root using the standard and modified Dickey-Fuller tests. The null hypothesis of a presence of the unit root is rejected. For example, the DF test statistics for cheddar barrel price, cheddar block price and milk price are -3.90, -3.71 and -3.26, respectively. These values are below the DF test statistic critical value at the 10% significance level, -3.13 (i.e. the null hypothesis of the unit root is rejected). These tests' outcomes suggest that the analyzed price series are stationary.

cheddar block price as the dependent variable. The estimation results along with the outcomes of statistical tests are summarized in Table 2<sup>13</sup>.

The estimation results indicate that the estimated coefficients for the current month price and its first lag are statistically significant for the increasing phase of milk price, and only the estimated coefficient for the current month price is statistically significant for the decreasing phase of milk price. This empirical evidence reflects a presence of asymmetry in the speed of the cheese price adjustment. All estimated coefficients for the segmented phases of milk price are statistically significant from zero at the 1% significance level. The explanatory power of the model is high, suggesting that the cumulative changes in milk price explain approximately 76% of the cumulative changes in cheese price.

The estimated model allows distinguishing between the immediate (i.e. the current month) and cumulative (i.e. the current and lagged months) effects of changes in milk price on the cheese price. The cumulative effect of the milk price increase is exactly the same as of the milk price decrease (i.e. symmetric in terms of the magnitude of cheese price response). The magnitude of cost pass-through is 0.64. The null hypothesis  $\beta_0^+ + \beta_1^+ = \beta_0^-$  fails to be rejected<sup>14</sup>. The null hypotheses of a perfectly competitive pricing  $\beta_0^+ + \beta_1^+ = 1$  and  $\beta_0^- = 1$  are rejected in favor of the alternative hypotheses  $\beta_0^+ + \beta_1^+ < 1$  and  $\beta_0^- < 1$ . Furthermore, the null hypotheses of a profit-maximizing monopoly pricing (linear demand)  $\beta_0^+ + \beta_1^+ = 0.5$  and  $\beta_0^- = 0.5$  are rejected in favor of the alternative hypotheses  $\beta_0^+ + \beta_1^+ > 0.5$  and  $\beta_0^- > 0.5$ . The magnitude of cost pass-through equal to 0.64 along with the T-test outcomes suggest that the wholesale cheese pricing practice used on CME spot cheese market is consistent with a profit-maximizing behavior of oligopoly in the market with linear demand and constant marginal cost.

The immediate impact (i.e. the current month effect) of the increasing and decreasing phases of milk price on the cheese price is somewhat different from the pattern discussed above. The estimated coefficient for the current month milk price-increase is 1.23, and the estimated coefficient for the current month milk price-decrease is 0.64. The current month cheese price adjustment is asymmetric, as indicated by the magnitude of cost pass-through and the T-test outcome. The null hypothesis of a symmetric adjustment of the cheese price to increases and decreases in milk price  $\beta_0^+ = \beta_0^-$  is rejected in favor of the alternative hypothesis of a positive asymmetric adjustment  $\beta_0^+ > \beta_0^-$ . The null hypotheses of a perfectly competitive pricing  $\beta_0^+ = 1$  and  $\beta_0^- = 1$  are rejected in favor of the alternative hypotheses  $\beta_0^+ > 1$  and  $\beta_0^- < 1$  for the milk price increase and decrease, respectively.

<sup>13</sup> As indicated by the Durbin-Watson statistics, there is a presence of autocorrelation in the estimated models (the magnitude of DW-Statistic in the cheddar block model is 1.28; Table 2). Given that the OLS estimator is unbiased in the presence of autocorrelation, the magnitude of the estimated coefficients is not affected by this process, but the standard errors of the estimated coefficients are affected. The autocorrelation-robust standard errors are computed based on the Newey-West approach; these standard errors are used to conduct all statistical tests.

<sup>14</sup> The outcomes of statistical tests on the wholesale cheese pricing methods are presented in Table 2. These tests were conducted using a one-tailed T-test and the 10% significance level.

The magnitude of the estimated coefficients for the current month changes in milk price and T-test outcomes provide evidence on a presence of imperfectly competitive pricing. The current month milk price increase is transmitted at a much higher rate than the current month milk price decrease; the ratio of the former to the latter is equal to 1.92. Furthermore, the milk price-decrease transmission is incomplete (0.64), and the milk price-increase transmission is more than a complete (1.23). The first effect is consistent with the profit-maximizing behavior of oligopoly in the market with linear demand and constant marginal cost. The second effect is consistent with the profit-maximizing behavior of monopoly/oligopoly in the market with non-linear demand and constant marginal cost.

The wholesale margin analysis can help understand the observed pricing behavior in the case of the cumulative and immediate effects of milk price changes. The wholesale margin behavior depends on the magnitude of cost pass-through<sup>15</sup>. First, consider the cumulative effect case, where the cheese price response is symmetric to the increase and decrease in milk price and the cost pass-through is incomplete. If milk price increases (decreases) by \$1/10 pounds, cheese price increases (decreases) by \$0.64/pound and wholesale margin decreases (increases) by \$0.36/pound. If the cost pass-through is incomplete, an increase (a decrease) in milk price causes the wholesale margin to decrease (increase). This empirical evidence may suggest that cheese wholesalers use an output (cheese) price stabilization practice.

Second, in the case of the immediate effect of milk price change, the cheese price response is asymmetric. Furthermore, the rate of milk price-increase transmission is greater than one, and the rate of milk price-decrease transmission is smaller than one. If milk price increases by \$1/10 pounds, cheese price increases by \$1.23/pound and wholesale margin increases by \$0.23/pound. If milk price decreases by \$1/10 pounds, cheese price decreases by \$0.64/pound and wholesale margin increases by \$0.38/pound.

Finally, we calculate milk price transmission elasticities. During the analyzed period of time, the average CME cheddar cheese block price is \$1.55/pound and the average milk price (in terms of the cost of milk used in cheese manufacturing) is \$1.48/pound. The ratio of milk price to cheese price is 0.95 (i.e. the share of farm value of milk in the wholesale cheese price). The current month price transmission elasticities are 1.17 for milk price-increase and 0.61 for milk price-decrease. The current month increase (decrease) in milk price by 1% leads to a 1.17% (0.61%) increase (decrease) in the CME cheddar block price. When the cumulative effect of milk price changes is considered, both the increase and decrease in milk price cause the same magnitude response in the CME cheddar block price. An increase (a decrease) in milk price by 1% causes a 0.61% increase (decrease) in the CME cheddar block price.

## Conclusion

The empirical evidence on the mechanism of vertical price transmission and the nature of cost pass-through at the wholesale market for cheddar cheese on the Chicago Mercantile Exchange indicates that pricing practices used by cheese wholesalers are not consistent with perfect

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<sup>15</sup> Equations (1) and (3) and the estimates of cost pass-through are used to determine the response of wholesale cheese price and wholesale margin to the changes in milk price.

competition, but tend to be consistent with pricing methods used by profit-maximizing oligopolists. This empirical evidence is consistent with pricing strategies that may be expected to be found in markets with structural characteristics similar to the CME spot cheese market: a relatively small number of sellers (i.e. high market concentration) trade a highly standardized (homogeneous) product in a market environment with inelastic demand and limited entry.

The empirical findings presented in the article indicate that the transmission of milk price-decrease is always incomplete. In contrast, the transmission of milk price-increase may be either incomplete or more than complete depending on the time period considered. It takes two months to pass on milk price increase, and it takes only one month to pass on milk price decrease. The pattern of the immediate impact of changes in milk price reflects a presence of a significant asymmetry. However, when the cumulative changes in milk price are taken into account, the milk price transmission (cost pass through) is incomplete. A milk price increase leads to a decrease in wholesale cheese margin, and a milk price decrease leads to an increase in wholesale cheese margin.

In summary, the overall empirical evidence may suggest that the wholesale cheese pricing practice used by cheese sellers on the Chicago Mercantile Exchange spot cheese market is an output (cheese) price stabilization. In a typical wholesale market, wholesalers use a fixed-percentage markup pricing method (a margin stabilization strategy). The CME spot cheese market is not a typical wholesale market. The CME spot cheese market is a thin (low volume) market, which prices are used as reference prices in cheese contracts used to transact practically all cheese produced in the country. Furthermore, the analyzed market is a low margin market. The wholesale cheese margin was on average 5% of the wholesale cheese price during the analyzed period of time. The cheese price stabilization pricing method used by cheese wholesalers is consistent with the nature of the CME spot cheese market and its role in the United States dairy industry pricing.

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## Appendix

**Table 1.** Chicago Mercantile Exchange (CME) spot cheese market: Cheddar cheese sales and wholesale cheese prices (2000-2013).

Year	CME cheddar sales (carloads <sup>1</sup> )		Cheese production (mill pounds)		CME cheddar sales as a percentage of cheese production		CME		Wholesale price		USDA NASS <sup>2</sup>	
	barrel	block	cheddar	all varieties	cheddar	all varieties	barrel	block	barrel	block	barrel	block
2000	584	623	2,819	8,258	1.80	0.61	1.1109	1.1465	1.0985	1.1332		
2001	209	501	2,747	8,261	1.09	0.36	1.4052	1.4386	1.4039	1.4165		
2002	194	644	2,822	8,547	1.25	0.41	1.1438	1.1822	1.1575	1.1808		
2003	109	590	2,701	8,557	1.09	0.34	1.2703	1.3172	1.2771	1.297		
2004	239	806	3,004	8,873	1.46	0.49	1.6036	1.6492	1.6216	1.6325		
2005	190	805	3,046	9,149	1.37	0.46	1.4484	1.4928	1.4621	1.4821		
2006	180	353	3,124	9,525	0.72	0.24	1.219	1.2385	1.2305	1.2318		
2007	485	451	3,057	9,777	1.29	0.40	1.7411	1.7578	1.7267	1.7172		
2008	492	704	3,186	9,913	1.58	0.51	1.8357	1.8558	1.8836	1.8801		
2009	545	1,179	3,207	10,109	2.26	0.72	1.2518	1.2961	1.2734	1.2900		
2010	550	592	3,235	10,443	1.48	0.46	1.4751	1.4964	1.5033	1.5138		
2011	496	591	3,096	10,595	1.47	0.43	1.7870	1.8064	1.8146	1.8084		
2012	446	457	3,147	10,890	1.21	0.35	1.6599	1.6980	N/A	N/A		
2013	389	466	3,189	11,101	1.13	0.32	1.7165	1.7642	N/A	N/A		
<b>Average</b>	<b>365</b>	<b>626</b>	<b>3,027</b>	<b>9,571</b>	<b>1.37</b>	<b>0.44</b>	<b>1.4763</b>	<b>1.5100</b>	<b>1.4544</b>	<b>1.4653</b>		

<sup>1</sup>A carload includes 40,000-44,000 pounds of cheese. The conversion is made assuming that the carload is 42,000 pounds of cheese.

<sup>2</sup>USDA NASS cheese prices are survey-based prices. Dairy processors report cheese prices, which are tied to the CME spot cheese prices due to the nature of pricing systems used in cheese contracts.

**Table 2.** Chicago Mercantile Exchange (CME) spot cheese market: The OLS estimation results of cost pass-through (CPT) and the hypotheses test outcomes on wholesale cheese pricing (2000 – 2014).

Independent variable	Dependent variable: CME cheddar block price		CME wholesale cheese pricing practices: hypotheses tests (T-ratio; p-value)	
	Est. coef. (CPT)	T-ratio	The cumulative effect of changes in FP	
$FP\_INC_t^* (\beta_0^+)$	1.23*	7.62	$H_0: \beta_0^+ + \beta_1^+ = \beta_0^-$ fails to be rejected $\{Ha: \beta_0^+ + \beta_1^+ > \beta_0^-\}$ (0.86; 0.3931)	
$FP\_INC_{t-1}^* (\beta_1^+)$	-0.58*	-3.24	$H_0: \beta_0^+ + \beta_1^+ = 1$ is rejected in favor of $Ha: \beta_0^+ + \beta_1^+ < 1$ (-7.30; 0.0000)	
$FP\_DEC_t^* (\beta_0^-)$	0.64*	12.04	$H_0: \beta_0^+ + \beta_1^+ = 0.5$ is rejected in favor of $Ha: \beta_0^+ + \beta_1^+ > 0.5$ (3.03; 0.0029)	
Constant	0.03	1.47	$H_0: \beta_0^- = 1$ is rejected in favor of $Ha: \beta_0^- < 1$ (-6.77; 0.0000)	
$\beta_0^+ + \beta_1^+$	0.64	12.90	$H_0: \beta_0^- = 0.5$ is rejected in favor of $Ha: \beta_0^- > 0.5$ (2.64; 0.0091)	
DW-statistic		1.28	<i>The immediate (current month) effect of changes in FP</i>	
R2		0.76	$H_0: \beta_0^+ = \beta_0^-$ is rejected in favor of $Ha: \beta_0^+ > \beta_0^-$ (3.26; 0.0014)	
Sample size		178	$H_0: \beta_0^+ = 1$ is rejected in favor of $Ha: \beta_0^+ > 1$ (1.41; 0.1611)	
			$H_0: \beta_0^- = 1$ is rejected in favor of $Ha: \beta_0^- < 1$ (-6.77; 0.0000)	
			$H_0: \beta_0^- = 0.5$ is rejected in favor of $Ha: \beta_0^- > 0.5$ (2.64; 0.0091)	

\*The estimated coefficient is statistically significant at the 1% significance level.  
 $H_0: \beta=0$  and  $Ha: \beta \neq 0$ ; the T-statistic ( $d/df=174$ ) rejection regions are  $(-\infty; -2.58]$  and  $[2.58; +\infty)$ .  
 A set of hypotheses on wholesale cheese pricing practices (one-tailed T-test, 10% significance level):  
 $H_0: CPT = c$  is rejected in favor of  $Ha: CPT > c$ : the T-statistic rejection region is  $[1.28; +\infty)$ ;  
 $H_0: CPT = c$  is rejected in favor of  $Ha: CPT < c$ : the T-statistic rejection region is  $(-\infty; -1.28]$ .  
 $c$  denotes the CPT magnitude:  $c=1$  under perfect competition,  $c=0.5$  under monopoly with linear demand,  $0.5 < c < 1$  under oligopoly with linear demand, and  $c > 1$  under monopoly/oligopoly with non-linear demand.  
 $H_0: CPT^{**} = CPT^{-}$  (symmetry) is rejected in favor of  $Ha: CPT^{**} > CPT^{-}$  (positive asymmetry): the T-statistic rejection region is  $[1.28; +\infty)$ .  
 All T-ratios are computed using the autocorrelation-adjusted standard errors (Newey-West approach).