From Auckland to Eau Claire: Price Transmission from International Dairy Markets to Local U.S. Milksheds

by

John Newton

From Auckland to Eau Claire: Price Transmission from International Dairy Markets to Local U.S. Milksheds

John Newton*

Paper presented at the NCCC-134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management
St. Louis, Missouri, April 18-19, 2016

John Newton can be reached at: john.newton247@gmail.com

From Auckland to Eau Claire: Price Transmission from International Dairy Markets to Local U.S. Milksheds

Abstract

The price relationships governing dairy commodity price transmission among the U.S., Oceania, and EU markets are considered using Vector Autoregressive and Vector Error Correction models. Results demonstrate a one-way price relationship for U.S. dry milk powders as price shocks in Oceania and the European Union spread to the U.S. while U.S. price shocks do not spread into those markets. U.S. prices for cheddar and butter are impacted by price shocks in Oceania and the EU, however, U.S. price shocks also spread the Oceania market and may reflect potential arbitrage opportunities. Historically thought to be shielded from international prices through low import quotas and high out-of-quota tariffs these results are the first to empirically demonstrate that U.S. dairy commodity prices and farm-gate milk prices are influenced in both the long-run and short run by international dairy commodity prices.

Keywords: Dairy, Trade, Vector Error Correction, Vector Autoregression

Introduction

The global dairy economy now includes more than 175 trading partners and is fast approaching $100 billion dollars in total dairy exports (United Nations, 2015). Of the $94 billion dollars in dairy products exported in 2014, 87 percent originated from the big-five dairy exporters including Australia, the European Union, New Zealand, and the United States. A common measure of market concentration, the Herfindahl-Hirschman Index, was estimated for the global dairy export sector to be 0.41 and suggests a high concentration among dairy exporters. Despite such high levels of industry concentration, prior literature suggests that the law of one price does not hold and that location and currency-adjusted milk and dairy commodity price levels differ considerably across exporting countries. Empirical evidence from Gould and Villarreal (2002) and Carvalho et al. (2015) suggest that United States milk and dairy commodity prices are independent of shocks to international dairy prices.

There are several reasons to revisit the findings of these studies with respect to international and U.S. dairy price relationships. First, the Gould and Villarreal analysis was conducted at a time when the U.S. had a trade balance in total milk solids equivalent to only 1.2 percent of the U.S. milk production volume and a negative trade balance with respect to milk fats, Figure 1.[1] However, over the past decade, financial assistance provided to dairy exporters from USDA's Dairy Export Incentive Program and the farmer-funded Cooperatives Working Together program have helped to increase U.S. dairy product exports and to position the U.S. as a consistent and reliable dairy trading partner (Price 2004). By 2014 the U.S. exported a record 15.4 percent of the total milk solids volume produced worth as estimated $7.1 billion dollars. Now that the U.S. exports a larger

[1] Total milk solids include milk fat, protein, and lactose. Trade balance of total solids and milk fats determined using the product composition of all dairy products imported and exported relative to domestic production of all milk solids.

percentage of total domestic production it is appropriate to revisit these international dairy commodity price relationships to determine if exposure to price shocks or the long-run price relationships have changed relative to the findings of previous research.

[Figure 1 Here]

Second, a majority of the dairy products produced for export in the U.S. are subject to weighted average milk pricing rules that may mask international milk price shocks (Manchester and Blayney, 2001). State or Federal Milk Marketing Orders help to ensure U.S. dairy farmers receive a minimum cash price for their milk through revenue pooling, price discrimination, and end-product price formulas (Newton, Thraen, and Novakovic, 2014). These orders determine monthly farm-gate milk prices based on weekly survey prices of cheddar, butter, dry milk powders, and an equalization payment from the revenue pool. The returns from the State or Federal marketing orders differ based on the utilization of milk in a marketing area (Bamba and Maynard, 2004; USDA AMS 2015; CDFA 2015). These equalization payments are generally higher in markets with high utilization of milk for beverage processing compared to areas where a majority of milk production is used to produce lower valued milk powders. For example, the U.S. all milk price averaged $23.97 per hundredweight during 2014, while the average price paid to dairy farmers delivering milk to Florida milk processors was $28.23 per hundredweight and the average paid to California dairy farmers was $22.10 per hundredweight over this same time period (USDA, NASS 2015). As a result, national average U.S. milk prices do not reveal spatial differences in milk prices or the commodity price relationships that defines U.S. end-product milk pricing formulas. As a consequence, Carvalho et al. (2015) omit the intermediate pricing steps and may potentially underestimate the impact of international price shocks on U.S. milk prices defined as: international dairy commodity prices → U.S. commodity prices → U.S. regional milk prices → U.S. national average milk price. Evidence of co-integrating relationships or price transmission between U.S. and international dairy commodity prices may challenge the finding that U.S. milk prices are independent of global dairy markets. By nature of the USDA end-product pricing formulas any evidence of domestic and international commodity price relationships would extend to farm-level and national average U.S. milk prices.

Empirical literature on price transmission effects in dairy markets have examined the relationship among national average milk prices in international milk markets using vector error correction models (Carvalho et al. 2015); modeled price transmission between farm and retail prices using threshold vector error correction models (Hahn et al. 2015); studied the causal relationships between the prices of milk in selected EU countries (Tluczak 2012); modeled price transmission and asymmetric adjustment in the Spanish dairy sector (Serra and Goodwin 2002); measured correlations between U.S. and international dry milk product prices (Gould and Villarreal 2002); and identified asymmetry in farm-retail price transmission for major dairy products (Kinnucan and Forker 1986; Capps and Sherwell 2005). This article is the first to analyze the global commodity price relationships for the key dairy commodities governing U.S. and farm-level milk prices using vector autoregressive (VAR) and vector error correction models (VECM). The article proceeds with a discussion of global milk price and trade trends. In the following section descriptive statistics and test results for stationarity and co-integration are presented. Next, based on the stationarity and co-integration test results VAR or VEC models of U.S. and international dairy commodity prices are estimated (e.g. Carvalho et al. 2015, and Hahn et al. 2015). Then, USDA end-product pricing formulas and regional utilizations of milk are examined to identify parts of the U.S. most sensitive to shocks in international dairy commodity prices. The article concludes by identifying possible causes for observed price effects in global dairy markets.

Global Dairy Trade

Since the early 1990's the U.S. has been party to 18 bi-lateral free trade agreements and three multi-lateral trade agreements with direct implications on dairy export opportunities. Yeboah, Shaik, and Agyekum (2015) and Vitaliano (2016) provide a summary of U.S. trade agreements as they pertain to dairy trade. Notable multi-lateral trade agreements include the 1986 to 1994 Uruguay Round, the 1994 North American Free Trade Agreement, and the 2015 Trans Pacific Partnership. Specifically, the Uruguay Round established binding limits on the use of agricultural export subsidies and domestic agricultural support regimes, converted all non-tariff import restrictions on agricultural products to bound tariffs, established science-based disciplines on trade barriers, and created the World Trade Organization (WTO) as an international institution to further liberalize world trade rules.

As a result of these trade agreements U.S. dairy exports have grown considerably, from $762 million dollars of U.S. dairy products exported in 1994 to $5.3 billion dollars of U.S. dairy products exported in 2015. Primary products exported included nonfat dry milk, cheeses and curds, and whey (USDA FAS, 2015). The recent rise in U.S. dairy product exports has positioned the U.S. as the third largest dairy exporter in the world behind only the EU and New Zealand. While the historical growth rate may be difficult to maintain, USDA projects the U.S. to grow in its role as a dairy supplier to the rest of the world (USDA, 2015). Growing demand in developing countries has driven the expansion in dairy trade. As incomes in developing counties increase, the demand for greater food variety in the form of meat, eggs, milk, and cheeses also increases. These changes in consumption patterns combined with population growth have contributed to large increases in the demand for animal products around the world (United Nations, 2011). The U.S. has not been the sole beneficiary of increased global demand for dairy products. The share of global dairy exports among the big four exporting countries has grown in recent years. In 2014 Australia, the European Union, New Zealand, and the United States combined to represent nearly 79 percent of global dairy exports, up from 74 percent in 2010 (USDA FAS, 2015).

Despite the big four exporters representing the majority of world dairy trade, Gould and Villarreal (2002) and Carvalho et al. (2015) found that U.S. milk prices were independent from world prices. Carvalho et al. (2015) did confirm price relationships among several country-level milk price regimes and specifically noted that shocks in the U.S. or New Zealand spread into other markets. For example, and as evidenced in Figure 2, annual average milk prices in the U.S., New Zealand, and the European Union exhibit high degrees of correlation.[2] Farmgate milk prices in the European Union, New Zealand, and the U.S. are derivative indices based on the prices of referenced dairy commodities such as cheese, butter, and milk powders (European Commission 2015; USDA AMS 2015). As a result, it is anticipated that the observed correlations in milk prices are driven by both

[2] Milk prices were adjusted based on historical exchange rates and prices based on U.S. milk solids content (butterfat and protein). Correlation coefficients are: U.S.-EU 0.85, EU-NZ 0.77, and U.S.-NZ 0.65.

long-run price relationships and short-term price shocks in one market transferring into another. The following sections will review these price dynamics.

[Figure 2 Here]

U.S., Oceania, and EU Dairy Commodity Prices

Price data for dairy commodities were collected from a variety of sources. Free on board butter, skim milk powder, whole milk powder, and Oceania cheddar prices were collected from USDA's Dairy Market News on a bi-weekly basis. European weekly average cheddar prices were collected from the United Kingdom's Department for Environment, Food & Rural Affairs.[3] Domestic prices for butter, cheddar, and nonfat dry milk were weekly averages of Chicago Mercantile Exchange (CME) spot market prices and domestic whole milk powder prices were collected from USDA's Dairy Market News. All prices were averaged on a bi-weekly frequency to align with the Oceania and EU prices reported by USDA's Dairy Market News. Table 1 reports the descriptive statistics for the three regions and four dairy commodity prices and Figure 3 shows the historical price relationships. Cross-region correlation was found to be higher in cheddar and milk powders as those products have a higher proportion of disappearance in export channels and higher U.S. tariff rate quota levels (USDA ERS, 2016). Relative to the U.S cross-region price correlation in butter was found to be 0.56 and 0.50 for Oceania and the European Union, respectively. The lower correlation found for butter is likely a result of the low export volume of U.S. butter relative to domestic consumption and the low TRQs on imported butter into the U.S. – thereby limiting price exposure from international markets (USDA ERS, 2016; USDA FAS, 2016).

[Table 1 Here]

[Figure 3 Here]

In order to test for price transmission or long-run price effects the first step is to test for stationarity. Non-stationary time series integrated of order one may have at least one co-integrating relationship. The co-integrating relationship allows for a linear combination of the non-stationary time series to be stationary and integrated of order zero. First, to test for stationarity an augmented Dickey-Fuller test and Kwiatkowski–Phillips–Schmidt–Shin test were evaluated for the log of dairy commodity price variables. Dickey-Fuller test statistics revealed that many of dairy commodity prices were trend non-stationary, Table 2. Next, prior to testing for co-integration, several information criteria were evaluated to determine the minimum lag length for evaluation. Then, based on the lag length from the Schwartz (1978) and Hanna and Quinn (1979) metrics, the Johansen (1992) trace test was conducted to identify the number of potential co-integrating relationships. Johansen co-integration test results are present in Table 3.

[Table 2 Here]

[Table 3 Here]

For a combination of prices which include at least one trend stationary variable and which do not exhibit a co-integrating relationship, price transmission may be identified using a p-lag vector autoregressive $VAR(p)$ model given by:

[3] Exchange rate data was used to convert the weekly European cheddar price into dollar per pound equivalent prices. European cheddar prices are not free on board export prices.

(1) $$\mathbf{Y_t} = \mathbf{\Pi_1 Y_{t-1}} + \cdots + \mathbf{\Pi_p Y_{t-p}} + \varepsilon_t$$

where $\mathbf{Y}_t = (y_{1t}, y_{2t}, ..., y_{nt})'$ denotes a $(n \times 1)$ vector of time series variables, $\mathbf{\Pi}_i$ are $(n \times n)$ coefficient matrices, and ε_t is an $(n \times 1)$ zero mean white noise vector process with a time invariant covariance matrix $\mathbf{\Sigma}$. For this analysis $\mathbf{Y}_t$ is a (3×1) matrix of first differences of the log of U.S., Oceania, and European dairy commodity price. Within a $VAR(p)$ model price transmissions across dairy markets are observed in the $\mathbf{\Pi}_i$ coefficient matrix. The sign and statistical significance are indicative of the type of price transmission from one market into another. For example, if no price transmission were present from market 2 to market 1 then π_{12}^i would not be statistically different from zero. Based on the results of the stationarity and co-integration tests a $VAR(p)$ model is appropriate to evaluate price relationships in butter and cheddar.

For a combination of prices that are trend non-stationary and which do exhibit at least one co-integrating relationship, long-run price relationships and price transmission, and the speed of price recovery following a shock are observed using a p-lag vector error correction model given by:

(2) $$\Delta\mathbf{Y_t} = \alpha\beta^T \mathbf{Y_{t-p}} + \mathbf{\Gamma_1}\Delta\mathbf{Y_{t-1}} + \cdots + \mathbf{\Gamma_{p-1}}\Delta\mathbf{Y_{t-p+1}} + \varepsilon_t$$

where Δ represents the first-difference operator, Γ measures the transitory effects similar to the $VAR(p)$ framework, α is the loading matrix and the long run relationships are contained in β. Milk powder prices were stationary when first-differenced and co-integrated. Based on the results of the stationarity and co-integration tests a vector error correction model is appropriate to evaluate price relationships in nonfat dry milk powder and whole milk powder.

Results of the VAR models for butter and cheese (Table 4) indicates that U.S. prices are influenced by prices in both the EU and Oceania, and are the first to empirically demonstrate that U.S. dairy commodity prices are not independent and are instead influenced by international dairy commodity prices. For butter, Oceania and EU price shocks manifest in the following period, while for cheese the price shocks occur in period $t+2$, i.e. four weeks. Additionally, VAR results for butter and cheddar confirm the findings of Carvalho et al. (2015) that price shocks in the U.S. market do spread into other dairy markets. Specifically, price shocks in the U.S. manifest in the following period, i.e. prices surveyed two weeks later, for Oceania cheddar and butter prices. U.S. price shocks do not impact EU cheddar of butter prices. Finally, for Oceania and the EU, price shocks in Oceania manifest in both the EU and U.S. over a period of one lag cycle (two weeks), while price shocks in the EU manifest in only the Oceania market.

[Table 4 Here]

For milk powders the results of the VEC models (Table 5) suggest similar pricing dynamics in that U.S. nonfat dry milk prices are influenced by Oceania and EU skim milk powder prices, while U.S. whole milk powder prices are influenced by EU whole milk powder prices. The long run effects indicate that a one percent decline in EU skim milk powder prices would be associated with an eight-tenths of one percent decline in U.S. nonfat dry milk prices and an even larger decrease in the Oceania skim milk powder price. For whole milk powder the co-integrating vector suggests that a one percent decline in the Oceania price would reduce the U.S. price by slightly more than one-third of one percent. The error correction coefficients for U.S. powder prices measure the speed of adjustment towards the long run equilibrium. The coefficient indicate feedback of 3 percent in nonfat dry milk and 6 percent in whole milk powder from a shock in the previous period. Importantly, results of the VEC suggest that price shocks in the U.S. market for nonfat dry milk or whole milk powder do not significantly alter prices in the Oceania or EU markets. Milk powder prices in the EU and Oceania show statistically significant co-movement in prices. Impulse response functions provide a visual overview of the dynamic price patterns associated with a one-time shock in a price series. Figure 4 illustrates the impulse response functions associated with a shock in U.S. cheddar prices.

[Table 5 Here]

[Figure 4 Here]

Transmission to Farm-Gate U.S. Milk Prices

As evidenced by the empirical models and the impulse response functions U.S. dairy commodity prices for cheddar, butter, and dry milk powders are influenced by the prices of dairy products in international markets. These wholesale dairy commodity prices are used by USDA to determine monthly prices for manufacturing and fluid milk (Bamba and Maynard, 2004; USDA AMS 2015). Then, using the announced Classified prices of milk and components, USDA Federal Milk Marketing Orders (FMMO) pool the prices of milk based on the utilization of milk in each class of utilization to determine a weighted average equalization payment from the pool. The price classifications are as follows: Class I for beverage milk; Class II for soft dairy products like ice cream and yogurt; Class III for cheese; and Class IV for butter and powder. There are currently 10 FMMO marketing areas, and each marketing area independently derives a weighted average pool equalization payment based on the monthly utilization of milk. The FMMO marketing areas are identified in Figure 5.

[Figure 5 Here]

Since the utilizations of milk differ by marketing area it follows then that the sensitivity to global price shocks would also differ by marketing area. Table 6 identifies the product price formula coefficients used to determine the manufacturing milk prices. By way of first-order-conditions Table 6 also identifies the change in each Class price based on $1 per pound change in the commodity price. For example, a 10¢ per pound increase in the cheese price would increase the Class III milk price by 96¢ per hundredweight. A 10¢ per pound in the butter or nonfat dry milk price would increase the Class II and Class IV prices by 42¢ per hundredweight and 86¢ per hundredweight, respectively. Reviewing Table 6 as column vectors also shows which Classified prices the individual dairy commodities impact. For example, butter prices are used to derive the classified value for manufacturing Classes II through IV; cheese and dry whey prices impact only Class III manufacturing prices; and nonfat dry milk impacts Class II and IV manufacturing classes.[4]

[4] Butter is also a component of the Class I fluid milk price. Other commodities may impact Class I depending on the higher-of element of fluid milk pricing.

[Table 6 Here]

It follows then that FMMO pool equalization payments based on a high utilization of milk in Class III would be more sensitive to shocks in world cheese prices than areas with low utilization levels. Similarly, areas with higher utilizations in Class IV butter and nonfat powder manufacturing would be more sensitive to shocks in international prices for those commodities. Figure 6 and 7 identify the average utilization percentage in Class III and Class IV milk by marketing area for 2015.[5] Based on the average utilization rates, dairy farmers in Western states and the Pacific Northwest are more sensitive to shocks in the butter and power prices. Meanwhile, the Upper Midwest FMMO is the most sensitive to shocks in international cheeses prices given that 79 percent of the milk in the Upper Midwest pool is Class III. Farmers in other parts of the U.S. are not insulated from these price shocks, rather more balanced utilization of milk across the classes and differing values on Class I milk helps to offset price shocks confined to a single product category.

[Figure 6 and 7 Here]

Thus, while the milk of a single producer may not be used to manufacture a product sold in export markets, price transmission from global dairy markets does manifest at the farm level as domestic prices and pool equalization payments reflect the price of the U.S.-produced dairy products competing in domestic and overseas markets with foreign sourced commodities.

Conclusion

A common theme in recent empirical analyses of U.S. and international dairy price relationships was there were no price transmission effects into the U.S. from international dairy markets (Gould and Villarreal 2002, and Carvalho et al. 2015). Results of the VAR and VEC models suggest that U.S. dairy commodity prices for cheddar, butter, and dry milk powders are influenced by the prices of dairy products in international markets. Since dairy commodity prices for cheddar, butter, and dry milk powders are used to directly determine farm-gate milk prices, these results are the first evidence that international dairy prices do have a measurable effect on U.S. farm-gate milk prices. The impacts at the farm-level vary based on the utilization of milk across the product classifications. Model results also partially confirm the findings of Carvalho et al. (2015) in that U.S. cheddar and butter prices do spread into other dairy markets while price shocks in U.S. powder prices do not significantly spread into other markets.

The proportion of U.S. powder disappearance in export markets supports the one-way price relationship from international powder markets to the U.S. USDA commercial disappearance data indicate that 50% of U.S. nonfat dry milk disappearance is in export channels (USDA ERS 2015).[6] In the United States, surplus milk is used to produce dry milk powders and balance the supply of milk needed for fluid use or cream demand. As a result, dry milk powders are often the lowest priced commodity, and given the large export volume U.S. powder prices follow closely the price of milk powders sold on global dairy markets (USDA AMS 2015).

While powders represent a large portion of the U.S. dairy export portfolio, less than 10% of U.S. butter and cheese consumption occurs in export markets. Given the small role of U.S. butter and

[5] California milk used to produce butter and nonfat dry milk are 4a and milk used to produce cheeses is 4b.
[6] USDA does not report commercial disappearance of whole milk powder.

cheese in export channels, the presence of price transmission from U.S. butter and cheddar prices into other dairy markets can likely be explained by several economic factors. First, due to financial and physical shipping constraints, the U.S. is not positioned to be the primary supplier of cheeses and butter products to the Asian markets. Due to these cost constraints the U.S. market often serves to balance supply and demand for dairy commodities in these markets. Increases in the export volume of U.S. produced butter of cheeses often coincide with short supplies in competing dairy producing regions or increased demand in foreign markets. In such a case, a high tide raises all boats and price shocks in international markets manifest in the U.S. as global supply and demand conditions find equilibrium.

Second, when U.S. domestic supply and demand conditions lead to higher domestic dairy product prices relative the rest of the world, the U.S. market becomes an attractive export destination for Oceania or EU-produced butters, cheeses, and other products offering similar composition and manufacturing use, i.e. anhydrous milkfat. Arbitrage opportunities are profitable and dairy commodity imports increase when the difference between domestic dairy product prices and the prices for similar products produced in foreign markets exceed transaction costs. Transaction costs of importing dairy products include freight, insurance, and tariff rates. Tariff rates may be applied on a per unit basis (specific rate), as a percentage of the monetary value of the imported item (ad valorem), or both.[7] For importers of dairy products, an arbitrage opportunity is profitable when: $p_w \leq (p_{US} - \tau - c) \times (1+\lambda)^{-1}$, where p_w is the international price, p_{US} is the U.S. price, τ is the in-quota or out-of-quota tariff rate, c is the costs of freight and insurance, and λ is the ad valorem tax. An arbitrage opportunity developed in 2015 when the combined effect of the Russian embargo of EU cheese and the lifting of the EU milk quota system led to additional world butter supplies and lower international butter prices. While international butter prices were depressed, tight U.S. supplies of butter - a result of large export volumes in 2014 - led to record-high butter prices in the U.S. The combined effect of high domestic prices and low world prices led to a surge in U.S. imports of butter and butter substitutes in 2015. Butter imports were significant enough to trigger WTO-authorized butter safeguards imposing additional import tariffs to protect U.S. markets. High U.S. butter prices manifested in internal markets as demand by the U.S. food-service industry for foreign-produced and cheaper butter and butter substitutes increased international butter prices.

These examples highlight how the supply and demand conditions in the global dairy economy effectively link U.S. and international dairy commodity and milk prices. While the price levels are often different, it is the price response to shocks that is transmitted across international markets. These results are particularly important as representatives from twelve countries recently concluded negotiations for the Trans-Pacific Partnership. These results suggest that enhanced dairy trade opportunities as a result of the reduced tariff and non-tariff barriers to trade may further increase the degree of price transmission among global dairy exporters as exporters would be able to more quickly and more frequently take advantage of arbitrage opportunities in global markets. For U.S. producers, such an outcome could increase price variability and may potentially result in higher or lower domestic prices as export or import opportunities are expanded. These price relationships are important to monitor as U.S. end-product milk pricing formulas ensure that U.S.

[7] Tariff levels are determined whether or not the imported quantity enters the country under in-quota or out-of-quota access. For in-quota access a lower tariff rate is applied, while a higher-tier tariff is applied to any imports in excess of the quota.

dairy farmer income, profitability, and financial risk exposure will remain tied to both domestic and international dairy markets.

References:

California Department of Food and Agriculture. 2015. Dairy Pricing Overview. Available Online: https://www.cdfa.ca.gov/dairy/prices_main.html

Capps, O. and P. Sherwell. 2005. "Spatial Asymmetry in Farm-Retail Price Transmission Associated with Fluid Milk Products." Selected Paper prepared for presentation at the American Agricultural Economics Association Annual Meeting, Providence, Rhode Island.

Carvalho, G.R., D. Bessler, T. Hemme, E. Schroer-Merker. 2015. "Understanding Internal Milk Price Relationships." Selected Paper prepared for presentation at the Southern Agricultural Economics Association's 2015 Annual Meeting, Atlanta, Georgia, January 31-February 3, 2015

European Commission. 2015. Agricultural and Rural Development Milk Market Observatory. Available Online: http://ec.europa.eu/agriculture/milk-market-observatory/latest-statistics/productions-stocks_en.htm

Gould, B.W., and H.J. Villarreal . 2002. "A Descriptive Analysis of Recent Trends in the International Market for Dry Milk Products." Babcock Institute for International Dairy Research and Development, University of Wisconsin.

Hahn, W., H. Stewart, D.P. Blaney, and C. Davis. 2015. "Modeling Price Transmission between Farm and Retail Prices: A Soft Switches Approach." Selected Paper prepared for presentation at the 2015 AAEA & WAEA Joint Annual Meeting, San Francisco, California, 26-28 July 2015

Kinnucan, H.W. and Forker, O.D. 1987. "Asymmetry in Farm-Retail Price Transmission for Major Dairy Products." American Journal of Agricultural Economics. 69, 285-292.

Manchester, A.C. and D.P. Blayney. 2001. "Milk Pricing in the United States." Economic Research Service, U.S. Department of Agriculture. Agriculture Information Bulletin No 761.

Maynard, L., and I. Bamba. 2004. Hedging-Effectiveness of Milk Futures Using Value-At-Risk Procedures. Paper presented at the annual meetings of NCR-134, Applied Commodity Price Analysis, Forecasting, and Market Risk Management, St. Louis MO.

Newton, J., and T. Kuethe. "The Footprint of Chinese Demand for U.S. Soybeans." *farmdoc daily* (5):57, Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign, March 27, 2015.

Newton, J., C.S. Thraen, and A. Novakovic. 2014. "2014 Farm Bill: Key Factors to Consider with a California Federal Milk Marketing Order." farmdoc daily, Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign, March 27, 2014.

Nicholson, C. and M. Stephenson. 2015. "Margins During the Dairy Price Cycle – Will This Time Be Different." National Program on Dairy Markets and policy. Information Letter 15-03. Available Online: http://dairy.wisc.edu/PubPod/Pubs/IL15-03.pdf

Price, M. 2004. "Effects of U.S. Dairy Policies on Markets for Milk and Dairy Products." USDA Economic Research Service Technical Bulletin 1910.

Serra, T. and B. Goodwin. 2002. “Price Transmission and Asymmetric Adjustment in the Spanish Dairy Sector.” Selected Paper prepared for presentation at the Agricultural & Applied Economics Association’s 2002 Annual Meeting, Long Beach, California, July 28-31.

Smith, A. 2015. “Identifying Causal Effects in Time Series Models.” Selected Paper prepared for presentation at the Agricultural & Applied Economics Association’s 2015 Annual Meeting, San Francisco, California, July 27-28, 2015.

Tluczak, A. 2012. “Attempt to Identify the Causal Relationship Between the Prices of Milk in Selected EU Countries.” Acta Oeconomica Et Informatica 2. 47-49.

United Nations Comtrade Database. Accessed online August 7, 2015: http://comtrade.un.org/

United Nations. 2011. Foreign Agricultural Organization. “World Livestock 2011.” Food and Agriculture Organization of the United Nations. Rome, Italy.

United States Department of Agriculture. 2015. Agricultural Marketing Service Federal Milk Marketing Orders. Available online: http://www.ams.usda.gov/rules-regulations/moa/dairy

---. 2015. Agricultural Marketing Service Dairy market News. Available online: http://www.ams.usda.gov/market-news/dairy

---. 2015. Foreign Agricultural Service. Available online: https://apps.fas.usda.gov/gats/default.aspx

---. 2015. National Agricultural Statistics Service. Quickstats. Available Online: http://www.nass.usda.gov/Quick_Stats/

---. 2015. Office of the Chief Economist. Long-Term Agricultural Projections. Available Online: http://www.usda.gov/oce/commodity/projections/index.htm

Vitaliano, P. 2016. “Global Dairy Trade: Where Are We, How Did We Get Here and Where Are We Going?” Invited Paper prepared for the International Food and Agribusiness Management Association Special Issue: “Assessing the Status of Global Dairy Trade”.

Yeboah, O., S. Shaik, and A. Agyekum. 2015. “Potential Impact of TPP Trade Agreement on US Bilateral Agricultural Trade: Trade Creation of Trade Diversion.” Selected Paper prepared for presentation at the Southern Agricultural Economics Association’s 2015 Annual Meeting, Atlanta, Georgia, January 31-February 3, 2015

Zhao, J. and B. Goodwin. 2011. “Volatility Spillovers in Agricultural Commodity Markets: An Application Involving Implied Volatilities from Options Markets.” Selected Paper prepared for presentation at the Agricultural & Applied Economics Association’s 2011 AAEA & NAREA Joint Annual Meeting, Pittsburgh, Pennsylvania, July 24-26, 2011.

Figure 1. Total dairy product trade balance as a percentage of U.S. milk solids production, 2000 to Jan 2016

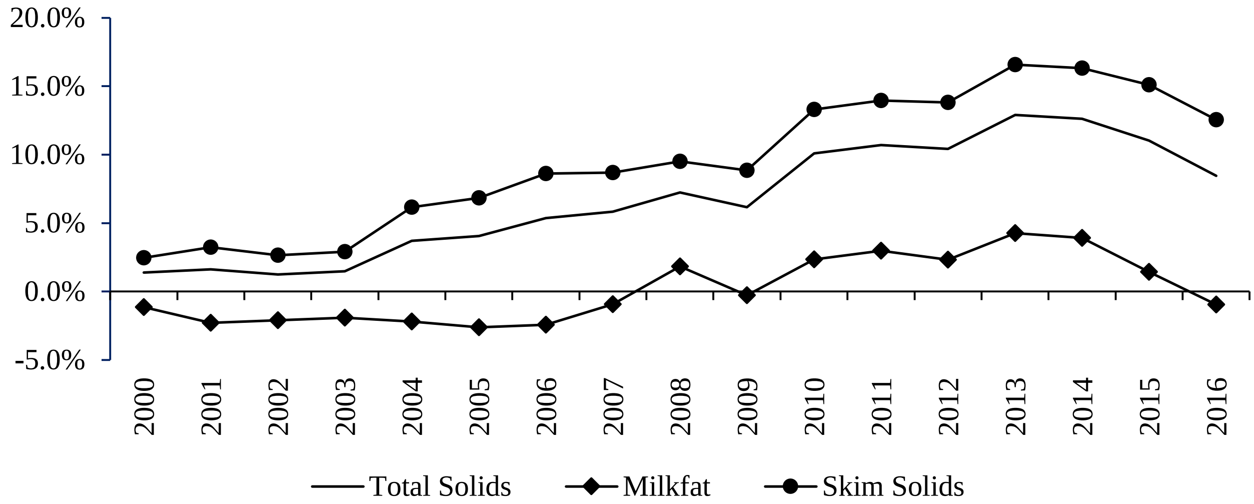
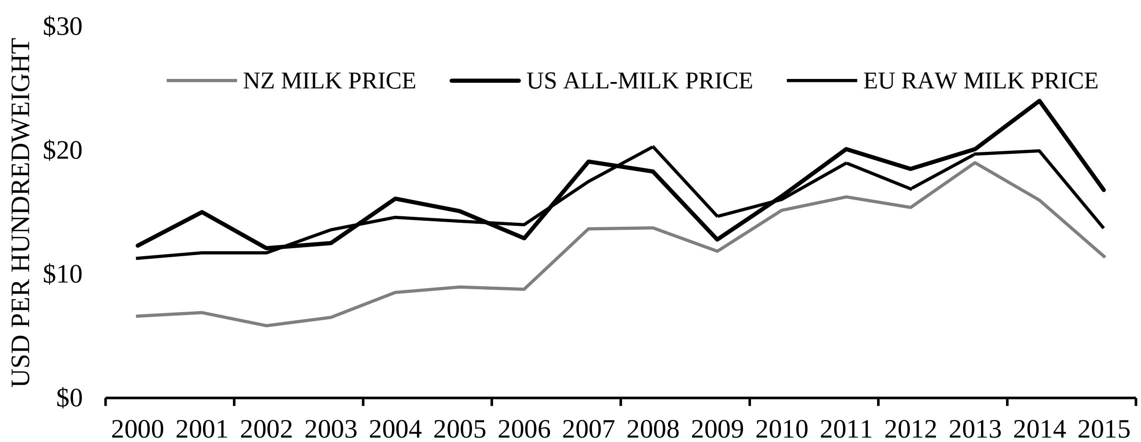
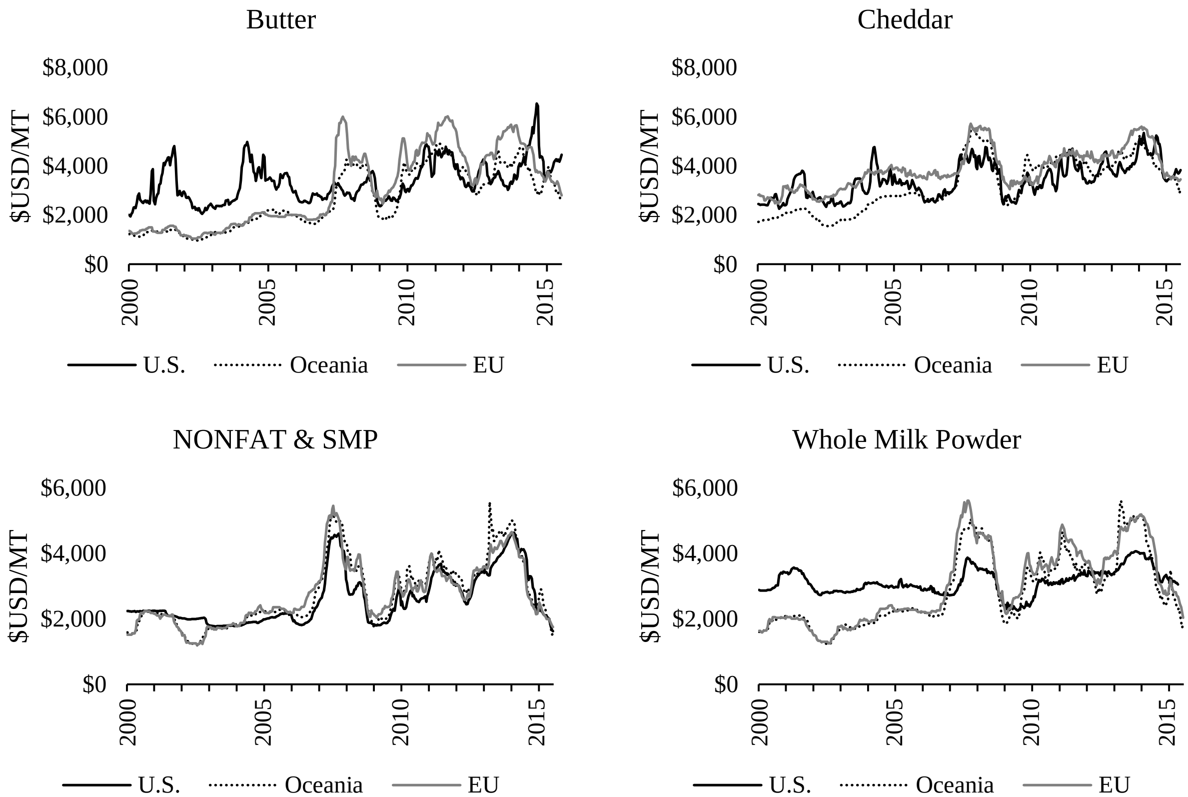


Figure 2. Farmgate milk prices for Europe, New Zealand, and U.S., 2000 to 2015



Note: New Zealand and EU Milk Prices Adjusted Using Historical Exchange Rates and U.S. Milk Solids and Fat Content

Figure 3. U.S., Oceania, and EU dairy commodity prices



Source: USDA AMS Dairy Market News, European Milk Market Observatory, Federal Reserve Economic Data

Figure 4. Impulse response function for nonfat dry milk and skim milk powder

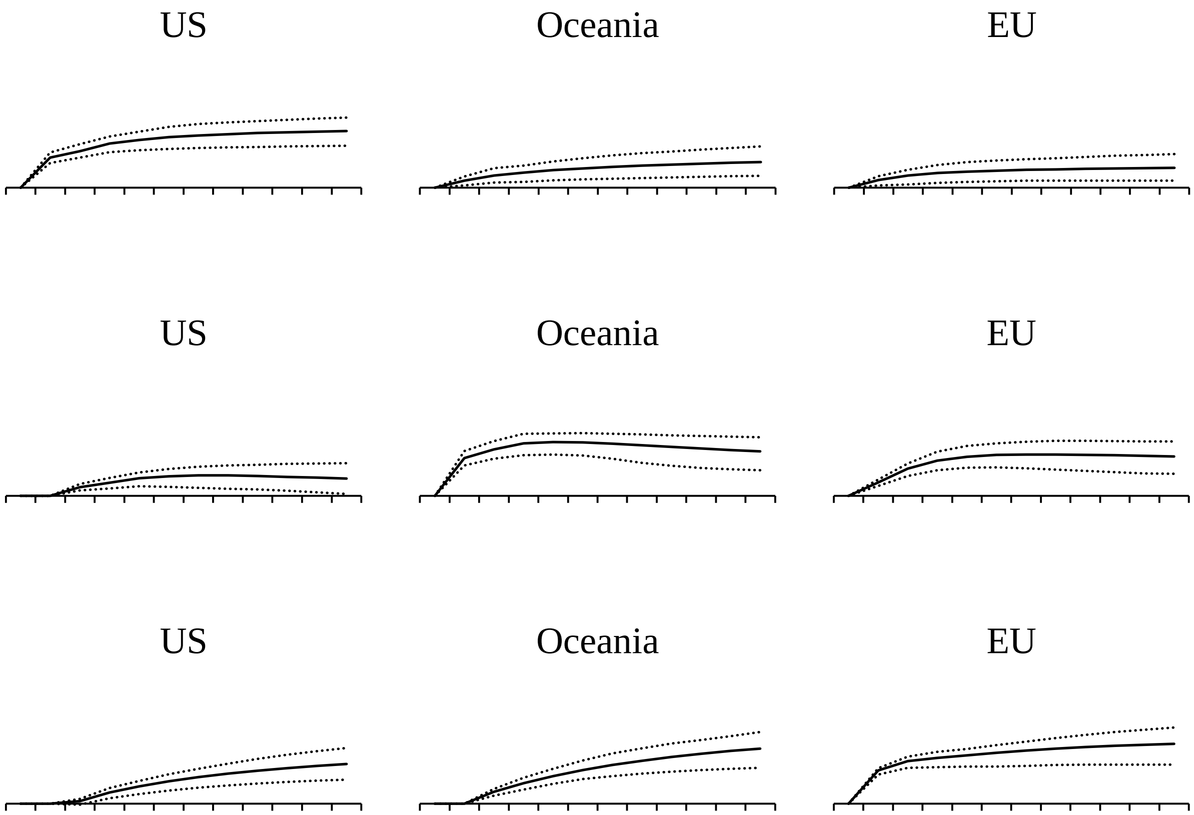
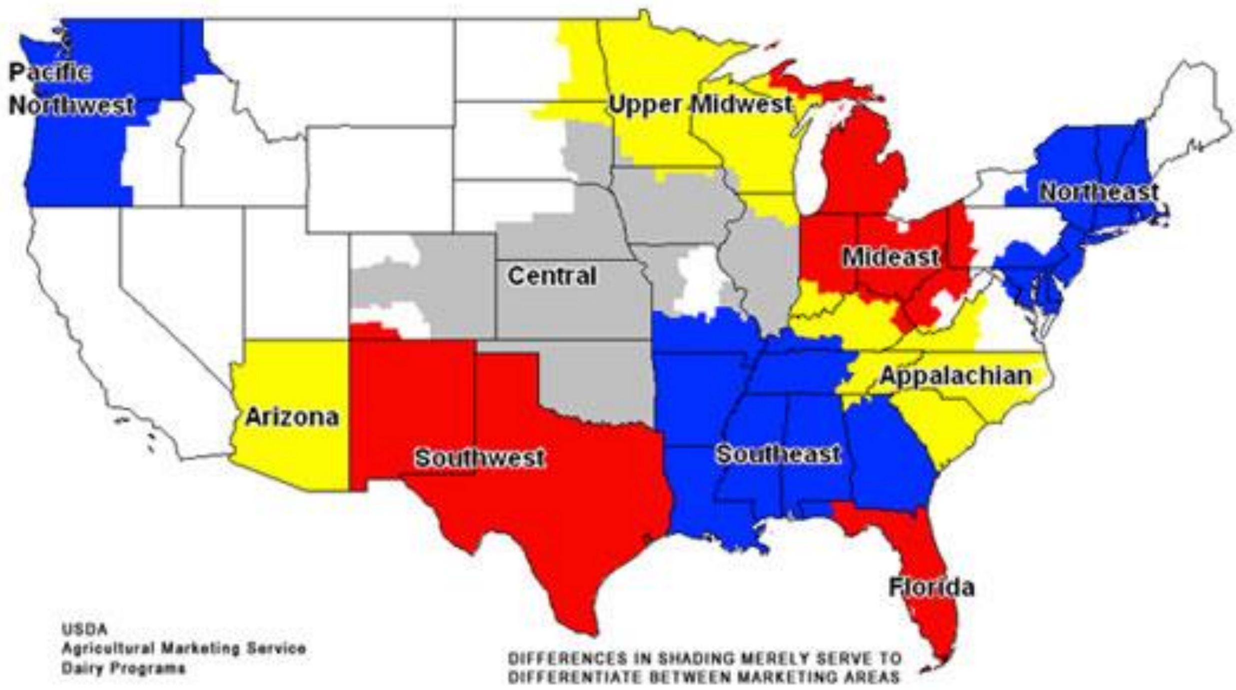


Figure 5. Federal Milk Marketing Orders



Source: USDA

Figure 6. Average Utilization of Milk in Class III/4b

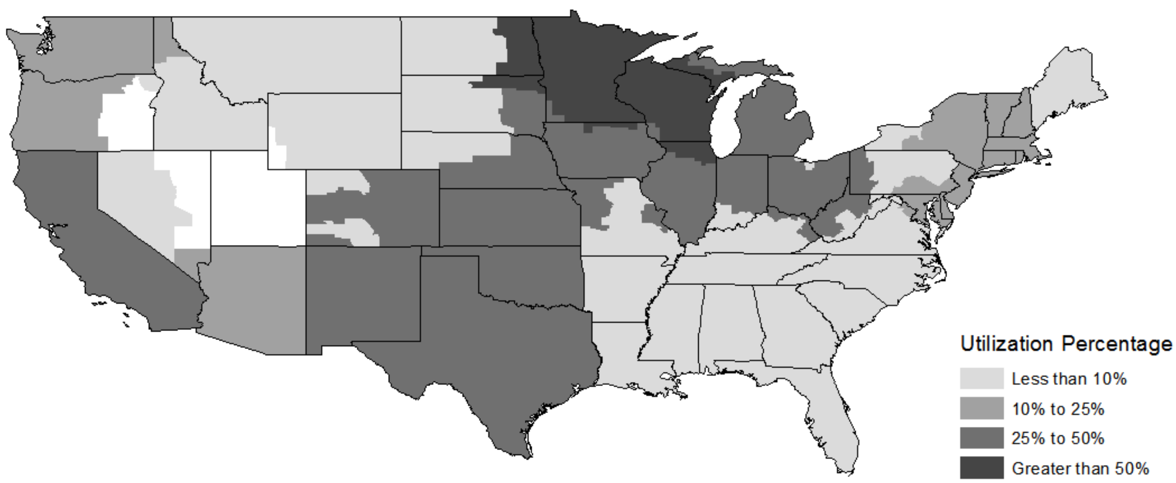


Figure 7. Average Utilization of Milk in Class IV/4a

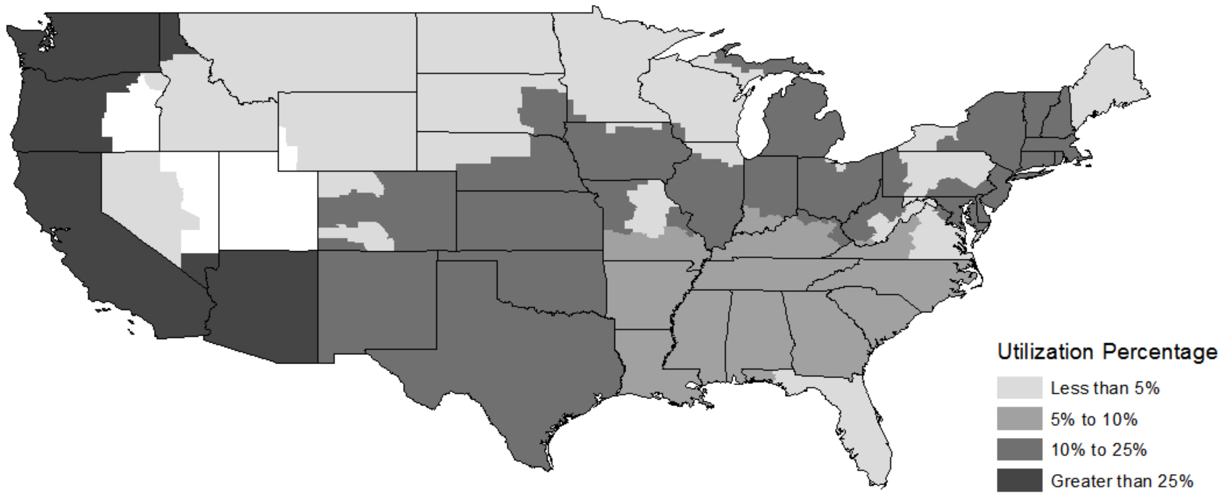


Table 1. Descriptive Statistics of Dairy Commodity Prices, dollars per metric ton

Variable	Region	Min	Median	Mean	Max
Butter					
	U.S.	1,944	3,283	3,408	6,545
	Oceania	962	2,212	2,655	4,900
	EU	1,050	3,683	3,832	5,723
Cheddar					
	U.S.	2,254	3,392	3,426	5,338
	Oceania	1,550	3,000	3,236	5,500
	EU	2,469	3,682	3,832	5723
NFDM					
	U.S.	1,621	2,232	2,560	4,627
	Oceania	1,188	2,250	2,724	5,562
	EU	1,200	2,350	2,684	5,450
WMP					
	U.S.	2,370	3,120	3,298	4,894
	Oceania	1,212	2,300	2,809	5,600
	EU	1,250	2,650	2,994	5,600

Source: USDA AMS Dairy Market News, European Milk Market Observatory (Exchange Rate Adjusted EU Cheddar Price)

Table 2. ADF Tests of Log of Price Series

Test Value DF_τ	Butter	Cheddar	NFDM & SMP	WMP
U.S.	-3.63	-3.68	-2.22	-2.11
Oceania	-2.29	-1.67	-1.99	-1.03
EU	-1.95	-1.17	-1.65	-1.52
Critical Values	1%	5%	10%	
	-3.98	-3.42	-3.13	

Table 3. Johansen co-integration tests for log of NFDM and WMP prices

	Test Statistics		Critical Value		
	Lag = 3	Lag = 2	10%	5%	1%
NFDM					
r ≤ 2	6.68	6.25	7.52	9.24	12.97
r ≤ 1	20.25	19.78	17.85	19.96	24.60
r = 0	56.70	63.88	32.00	34.91	41.07
WMP					
r ≤ 2	5.46	4.53	6.50	8.18	11.65
r ≤ 1	12.72	11.47	15.66	17.95	23.52
r = 0	30.99	30.00	28.71	31.52	37.22

Table 4. Vector autoregressive model for log of butter and cheddar prices

	Butter			Cheddar		
	ΔU.S.	ΔOceania	ΔEU	ΔU.S.	ΔOceania	ΔEU
Region (lag)						
ΔU.S.(1)	0.350***	0.058*	0.014	0.618***	0.081**	0.050
	(0.048)	(0.027)	(0.031)	(0.046)	(0.029)	(0.032)
ΔOceania(1)	0.162[a]	0.246***	0.174**	0.035	0.149**	0.205***
	(0.087)	(0.050)	(0.058)	(0.078)	(0.049)	(0.055)
ΔEU(1)	0.186*	0.184***	0.236***	0.010	0.107*	-0.117*
	(0.076)	(0.044)	(0.050)	(0.069)	(0.043)	(0.049)
ΔU.S.(2)	-0.219***	-0.022	0.018	-0.358***	-0.025	-0.044
	(0.048)	(0.027)	(0.031)	(0.047)	(0.029)	(0.033)
ΔOceania(2)	-0.068	0.127*	-0.006	0.160*	0.292***	0.113*
	(0.085)	(0.049)	(0.057)	(0.078)	(0.049)	(0.055)
ΔEU(2)	-0.139[a]	0.059	0.151**	0.128[a]	0.034	0.095[a]
	(0.077)	(0.045)	(0.051)	(0.069)	(0.043)	(0.049)
R^2	0.138	0.239	0.172	0.314	0.186	0.075

*Note: US reflects nonfat dry milk and Oceania and EU reflect skim milk powder. Lags and Standard errors are in parentheses. ***, **, *, and [a] denote significance level of <1%, 1%, 5% and 10%. Statistically significant price relationships shaded.*

Table 5. Vector error correction model for log of NFDM and WMP prices

	NFDM			WMP		
	ΔU.S.	ΔOceania	ΔEU	ΔU.S.	ΔOceania	ΔEU
Loading	-0.030**	-0.028	-0.011	-0.060***	-0.011	-0.038*
Parameters	(0.011)	(0.014)	(0.014)	(0.015)	(0.021)	(0.017)
	-0.024	-0.014	-0.023			
	(0.021)	(0.028)	(0.026)			
Co-integrating	1.00	0.00	-0.81	1.00	-0.362	-0.094
Vector	0.00	1.00	-1.07			
ΔU.S.(1)	0.152**	0.034	0.017	0.151**	-0.016	0.092
	(0.049)	(0.064)	(0.061)	(0.051)	(0.071)	(0.056)
ΔOceania(1)	0.232***	0.244***	0.234***	0.023	0.179***	0.202***
	(0.041)	(0.054)	(0.051)	(0.036)	(0.051)	(0.040)
ΔEU(1)	0.024	0.229***	0.300***	0.146**	0.451***	0.229***
	(0.045)	(0.058)	(0.055)	(0.045)	(0.064)	(0.051)
ΔU.S.(2)	0.149**	-0.033	0.002			
	(0.046)	(0.060)	(0.057)			
ΔOceania(2)	-0.014	0.090	0.061			
	(0.043)	(0.056)	(0.054)			
ΔEU(2)	0.102*	-0.011	-0.070			
	(0.046)	(0.059)	(0.057)			
Constant	0.030	-0.118***	0.030	0.272***	0.049	0.172*
	(0.024)	(0.032)	(0.030)	(0.067)	(0.071)	(0.075)

*Note: US reflects nonfat dry milk and Oceania and EU reflect skim milk powder. Lags and Standard errors are in parentheses. ***, **, *, and [a] denote significance level of <1%, 1%, 5% and 10%. Statistically significant price relationships shaded.*

Table 6. End-Product Pricing Formulas Under Federal Milk Marketing Orders

Milk Price	Butter	Cheese	Nonfat Dry Milk	Dry Whey	Make Allowance
Class II	4.2385	--	8.5982	--	-1.4774
Class III	0.4237	9.6393	--	5.8643	-3.1710
Class IV	4.2385	--	8.5982	--	-2.1697