Spatial Asymmetry in Farm-Retail Price Transmission Associated with Fluid Milk Products

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May 2005

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Selected Paper prepared for presentation at the American Agricultural Economics Association Annual Meeting,
Providence, Rhode Island

Abstract

Testing for asymmetric price transmission and calculating elasticities of price transmission are of great importance in applied economics. We analyze the behavior of tests for asymmetry according to the conventional Houck approach and to the von Cramon-Taubadel and Loy error correction model (ECM) approach. We also estimate the short-run and long-run elasticities of price transmission between the farm and retail levels of the marketing channel for whole milk and two percent milk for seven U.S. cities by model. We employ monthly data over the period from January 1994 to October 2002. Empirical results suggest that the farm-retail price transmission process for milk is asymmetric. Price transmission elasticities in conjunction with rising farm prices generally are larger than corresponding elasticities associated with falling farm prices. [JEL Classification: Q110, Q130].

Key words: asymmetric price transmission, elasticity price transmission; error correction model; fluid milk; city-level analysis

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1. Background

Testing for asymmetric price transmission and calculating elasticities of price transmission are of great importance in applied economics. The relationship between farm and retail prices provides insights into marketing efficiency as well as consumer and producer welfare. Elasticities in conjunction with the farm-to-retail price transmission process are defined as the percentage change in retail price of a product due to a one percent change in the corresponding farm price. As Aguiar and Santana (2002) pointed out, most empirical estimates of elasticities of price transmission have been obtained assuming symmetric price transmission, meaning that retail prices would respond in the same manner for both increases and decreases in farm prices. However, the extant literature is replete with evidence to indicate that asymmetric price transmissions indeed are very common. To illustrate, Peltzman (2000) found evidence of asymmetric price transmission in over two-thirds of the several hundred producer and consumer goods in the United States. Kinnucan and Forker (1987), Hahn (1990), and Bernard and Willett (1996) found that retail prices were more sensitive to increases in farm prices than to decreases in farm prices. Ward (1982) and Punyawadee, Boyd, and Faminow (1991), on the other hand, found that retail prices were more sensitive to decreases in farm prices than to increases in farm prices. Outside of agriculture, Borenstein, Cameron and Gilbert (1997) found that gasoline prices are more responsive to increases in oil prices than to decreases in oil prices.

The presence of asymmetric price transmission often is considered to be evidence of market failure or the abuse of market power (von Cramon-Taubadel and Meyer, 2000). Although Peltzman (2000) and von Cramon-Taubadel (1998) discussed many potential causes of asymmetric price transmission, empirical analyses of this phenomenon typically do not allow differentiation among the different possible causes. Moreover, Peltzman (2000) concluded that since asymmetric price transmission was prevalent in the majority of producer and consumer markets, standard economic theory, which does not account for this situation, was "wrong" (p.493). Importantly, while much of the empirical focus has been on methods to detect asymmetric price transmission, few analysts actually have computed the resulting elasticities of price transmission. This omission is curious because the computation of elasticities of price transmission is a natural by-product of the empirical analyses.

Over the last three decades, most empirical efforts to test for the presence of asymmetric price transmission have been based on a variable-splitting technique developed by Wolffram (1971) and later adapted by Houck (1977) and by Ward (1982). This technique widely has been employed in the agricultural economics literature in considering asymmetric price transmission. Examples include the examination of price asymmetry in spatial fed cattle markets (Bailey and Brorsen (1989)); price asymmetry in the U.S. pork marketing channel (Boyd and Brorsen (1988); Miller and Hayenga (2001)) and in the Alberta pork market (Punyawadee, Boyd, and Faminow (1991)); asymmetry in farm-retail price transmission in the dairy sector (Kinnucan and Forker (1987)); price asymmetry in the international wheat market (Mohanty, Peterson, and Kruse (1995)); price asymmetry in peanut butter (Zhang, Fletcher, and Carley (1995)); asymmetric price relationships in the U.S. broiler industry (Bernard and Willett (1996); price transmission asymmetry in pork and beef markets (Hahn, 1990); asymmetry in shipping point, wholesale and retail markets for red delicious apples (Willett, Hansmire, and Bernard (1997)); asymmetry in beef, lamb and pork in farm-retail price transmission in Australia (Griffith and Piggott (1994)) and asymmetry in farm to retail price transmission of fresh tomatoes, onions, powder milk, soluble coffee, rice, and beans in Brazil (Aguiar and Santana (2002)).

Von Cramon-Taubadel and Fahlbusch (1994) demonstrated that an asymmetric error correction model (ECM) based on the work of Granger and Lee (1989) could be used to test for asymmetric price transmission. Von Cramon-Taubadel and Loy (1999) extended this application of the asymmetric ECM and concluded that this method was more appropriate than the use of the conventional Houck approach if the price data under investigation were cointegrated. In this light, owing to the possibility that different methods employed to detect asymmetric price transmission may lead to different conclusions, a principal objective of this paper is to analyze the behavior of tests for asymmetry according to the conventional Houck approach and to the von Cramon-Taubadel and Loy ECM approach. In this comparison, we employ monthly data over the period January 1994 to October 2002 pertaining to farm and retail prices of whole milk and two percent milk from seven U.S. cities—Atlanta, Boston, Chicago, Dallas, Hartford, St. Louis, and Seattle. The comparison of these approaches not only adds to the literature on price asymmetry but also potentially adds to the robustness of the results. On the basis of this analysis, another principal objective is to estimate the elasticities of price transmission between the farm and retail levels of the marketing channel for whole milk and two percent milk by city and by model specification.

2. Methodology

In this section we present alternative approaches in detecting asymmetric price transmission. We initially present and discuss the "Houck approach," and subsequently we present and discuss the "asymmetric ECM approach." These approaches are appropriate in examining the price transmission process between farm and wholesale, wholesale and retail, and farm and retail levels of the marketing channel. Our emphasis is placed only on price transmission between the farm and retail levels of the vertical market system. Additionally, while most previous studies center attention on asymmetric responses at the national level, relatively few address spatial considerations. Pick, Karrenbrock, and Carmen (1990) studied price asymmetry in the California and Arizona citrus industry; Bailey and Brorsen (1989) investigated price asymmetry in spatial fed cattle markets; and Willett, Hansmire, and Bernard (1987) look at asymmetric price response behavior of red delicious apples in the Western North Central and Northeastern regions of the United States.

2.1 The "Houck Approach"

Houck (1977) developed a test for asymmetric price transmission based on the segmentation of price variables into increasing and decreasing phases. Other analysts, notably Boyd and Brorsen (1988); Kinnucan and Forker (1987); Bailey and Brorsen (1989); Zhang, Fletcher, and Carley (1995); Mohanty, Peterson, and Kruse (1995); Bernard and Willett (1966); Willett, Hansmire, and Bernard (1997), Peltzman (2000); and Aguiar (2002), followed suit. While these studies all differ in some ways from a technical point of view, we subsume them under the general heading labeled the "Houck approach."

Houck proposed a static asymmetric model that can be written as:

$$\Delta P_{rt} = a_0 + a_1 \Delta P_{ft}^{+} + a_2 \Delta P_{ft}^{-} + \in_t , \tag{1}$$

where P_{rt} and P_{ft} are retail and farm prices of the marketing chain, respectively, t = 1, 2, . . ., T, Δ is the first difference operator, and following Houck (1977),

$\Delta P_{ft}^{+} = P_{ft} - P_{ft-1}$, if $P_{ft} > P_{ft-1}$ and 0 otherwise, and $\Delta P_{ft}^{-} = P_{ft} - P_{ft-1}$, if $P_{ft} < P_{ft-1}$ and 0 otherwise. Implicit in the development of this model is the notion that changes in farm prices are drivers of changes in retail prices. To paraphrase Kinnucan and Forker (p. 286 1987), "farm prices are assumed to Granger cause retail prices and not vice versa." Lamm and Westcott (1981) provided evidence that for dairy products, indeed the direction of causality runs from the farm level to the retail level. As exhibited in Tables 1 and 2, the Granger causality tests associated with farm and retail prices of whole milk and two percent milk indigenous to this analysis support the underlying assumption that farm prices precede or Granger cause retail prices.

This support holds for all cities except Boston and Hartford. From July 1997 to September 2001, a dairy compact was in place in the Northeast (Bailey (2003)). One may speculate that the existence of the dairy compact may have interfered with the Granger causality pattern established in other cities.

Because of: (1) inertia in the food marketing system associated with storing, transporting, and processing fluid milk (Kinnucan and Forker (1987)); (2) imperfections such as diversity in market structure and differences in the assimilation and transmission of information at exchange points in the market channel (Ward (1982)); and (3) the nature of price reporting and collection methods (Hall et al 1981)), the response of retail prices to changes in farm level prices generally is not instantaneous, but instead is distributed over time. Lamm and Westcott (1981) noted that six months or less is required for retail dairy product prices to adjust fully to changes in the farm price of milk. Consequently, equation (1), a static formulation, may be rewritten as a dynamic representation:

$$\Delta P_{rt} = a_0 + \sum_{i=0}^{M1} a_{1i} \Delta P^{+}_{ft-i} + \sum_{i=0}^{M2} a_{2i} \Delta P^{-}_{ft-i} + \in_t \tag{2}$$

The a_{1i} coefficients in equation (2) represent the impact of rising farm prices on retail prices, and the a_{2i} coefficients in equation (2) represent the impact of falling farm prices on retail prices. M1 and M2 represent the length of the lags with regard to rising farm prices and falling farm prices respectively. As such, a formal test of the asymmetry hypothesis is:

$$H_0 : \sum_{i=0}^{M1} a_{1i} = \sum_{i=0}^{M2} a_{2i} \tag{3}$$

The appropriate test statistic then is either a t-test or an F-test owing to the fact that the respective sums in equation (3) constitute a linear combination of coefficients. A rejection of H_0 is evidence of asymmetry or non-reversibility in price transmission. If one fails to reject

H_0, then there exists evidence to support the notion of symmetry (or reversibility) in price transmission.

2.2 The "Asymmetric Error Correction Model Approach"

In agreement with Goodwin and Holt (1999), the literature dealing with price transmission for the most part has not paid proper attention to the time-series properties of the data. That is, with few exceptions, previous research, at least in the agricultural economics literature, has not considered the inherent nonstationarity of prices or long-run stationary equilibria (cointegration) relationships among prices. This limitation was recognized by von Cramon-Taubel (1998) in investigating asymmetric price behavior in German producer and wholesale hog markets. Goodwin and Holt (1999) evaluated price linkages among producers, wholesale, and retail marketing channels in US beef markets utilizing threshold cointegration methods introduced by Balke and Fomby (1997). Similarly, Goodwin and Harper (2000) investigated linkages among farm, wholesale, and retail markets utilizing cointegration techniques in analyzing price transmission, threshold behavior, and asymmetric adjustment in the U.S. pork sector. Finally, Goodwin and Piggott (2001) evaluated linkages among four corn and four soybean markets in North Carolina using cointegration methods.

The asymmetric ECM approach is motivated by the fact that all variants of the aforementioned Houck approach are not consistent with cointegration between the retail and farm price series (von Cramon-Taubadel (1998)); von Cramon-Taubadel and Loy (1999)). If P_{rt} and P_{ft} are cointegrated, then by the Engle-Granger Representation Theorem, we may develop an alternative specification for the price transmission process:

$$\Delta P_{rt} = b_0 + b_1 \Delta P_{ft} + b_2 ECT_{t-1} + \sum_{i=1}^{P_1} b_{3i} \Delta P_{rt-i} + \sum_{i=1}^{P_2} b_{4i} \; \Delta P_{ft-i} + v_t , \tag{4}$$

where $ECT_t = P_{rt} - g_0 - g_1 P_{ft}$ (residuals from the cointegrating relation between P_{rt} and P_{ft}). P_1 and P_2 represent the length of the lags associated with the change in retail price series and the change in the farm price series.

Granger and Lee (1989) proposed a modification to equation (4) that involves a Wolfram-type segmentation of the error correction term ECT into positive and negative components:

$$\Delta P_{rt} = b_0 + b_1 \Delta P_{ft} + b_2^+ ECT_{t-1}^+ + b_2^- ECT_{t-1}^- + \sum_{i=1}^{P_1} b_{3i} \Delta P_{rt-i} + \sum_{i=1}^{P_2} b_{4i} \Delta P_{ft-i} + v_t \tag{5}$$

Von Cramon-Taubadel and Loy (1999) made further modifications to equation to allow for the segmentation of ΔP_{ft}. Consequently, the asymmetric error correction model in our analysis is given by:

$$\Delta P_{rt} = b_0 + b_1^+ \Delta P_{ft}^+ + b_1^- \Delta P_{ft}^- + b_2^+ ECT_{t-1}^+ + b_2^- ECT_{t-1}^- + \sum_{i=1}^{P_1} b_{3i} \Delta P_{rt-i} + \sum_{i=1}^{P_2} b_{4i} \Delta P_{ft-i}^+ + \sum_{i=1}^{P_3} b_{4i}^- \Delta P_{ft-i}^- + v_t \tag{6}$$

Subsequently, we may rewrite and operationalize equation (6) as:

$$\Delta P_{rt} = b_0 + \sum_{i=0}^{P_2} b_{4i} \Delta P_{ft-i}^+ + \sum_{i=0}^{P_3} b_{4i}^- \Delta P_{ft-i}^- + b_2^+ ECT_{t-1}^+ + b_2^- ECT_{t-1}^- + \sum_{i=1}^{P_1} b_{3i} \Delta P_{rt-i} + v_t \tag{7}$$

Notice that equation (7) is tantamount to the Houck approach given by equation (2), except that equation (7) also contains three additional terms: $b_2^+ ECT_{t-1}^+$, $b_2^- ECT_{t-1}^-$ and $\sum_{i=1}^{P_1} b_{3i} \Delta P_{rt-i}$. Thus, the asymmetric ECM nests the “Houck”model. If any of the coefficients

b_2^+, b_2^-, and $b_{3i}(i=1,\ldots,P_1)$are statistically different from zero, the asymmetric ECM statistically is superior to the “Houck” model. A formal test of the asymmetry hypothesis using equation (7) is:

$$H_0 : \sum_{i=0}^{P_2} b_{4i}^{+} = \sum_{i=0}^{P_3} b_{4i}^{-} \text{ and } b_2^{+} = b_2^{-} \tag{8}$$

Again, because equation (8) involves a linear combination of structural coefficients, a joint F-test can be used to determine the symmetry or asymmetry of the price transmission process.

3. Data

Monthly undeflated (nominal) retail prices of two percent and whole milk and undeflated announced cooperative (farm level) blend prices for milk for the period, January 1994 to October 2002 from seven U.S. cities, were used. To create a farm price for whole milk and a farm price for two percent milk, adjustments to the cooperative blend price were made based on butterfat and components.[a] Our analysis rests on 106 monthly observations. Atlanta, Boston, Chicago, Dallas, Hartford, Seattle, and St. Louis were chosen arbitrarily to represent different regions of the country to achieve geographic diversity. Descriptive statistics associated with these respective price series are exhibited in Tables 3 and 4. The farm and retail prices are expressed in terms of dollars per gallon. The source of the data is the Agricultural Marketing Service, U.S. Department of Agriculture.

Average farm prices of whole milk range from \$1.28 per gallon (Seattle) to \$1.46 per gallon (Boston). Average retail prices of whole milk range from \$2.63 per gallon (Dallas) to \$3.29 per gallon (Seattle). Similar figures are evident for average farm and retail prices of two percent milk across these seven U.S. cities. Suffice it to say that noteworthy differences exist

[a] We are grateful to Bud Schwart, Extension Dairy Economist, at Texas A&M University for making these adjustments to the blend price.

in prices, both at the farm and retail levels, for the seven cities. In short, differences in farm and retail prices, as well as in farm-retail price spreads by city are likely the results of government policy and the cost of transporting fluid milk from surplus to deficit areas.

The next step is check on the cointegration between the respective farm price and retail price series. In Tables 5 and 6, we summarize the Johansen cointegration tests. Based on both the Trace test and the Maximal Eigenvalue test statistics, farm prices and retail prices of whole milk are cointegrated for the cities of Atlanta, Chicago, and Dallas. Farm prices and retail prices of two percent milk are cointegrated for all cities except Boston and Hartford. Consequently, we may apply the asymmetric ECM to the respective cointegrated series.

Again, we speculate that the lack of cointegration of farm and retail prices in Boston and in Hartford may be attributable to the institution of the Northeast Compact. Bailey (2003) found that retail prices were higher by roughly 30 to 31 cents per gallon in these cities when the Northeast Compact was in effect compared to the situation when the Northeast Compact was not in effect. Also, Bailey (2003) found that the farm-to-retail price spread was higher during the presence of the Northeast Compact.

4. Estimation Procedures

To accommodate the Houck approach we estimate equation (2) for the milk products and the seven representative cities. Similarly, we estimate equation (7) to accommodate the ECM approach. Except for Boston and Hartford, roughly 40 (60) percent of the observations are for declines (hikes) in farm prices. In the cases of Boston and Hartford, the observations are roughly evenly split for decreases in farm prices and for increases in farm prices. Thus, a sufficient number of observations exist to reliably assess the asymmetry issue from a statistical standpoint.

In some of the equations, serial correlation is evident; therefore, for these equations, generalized least squares estimates are presented. In those equations in which serial correlation is not evident, we present ordinary least squares estimates. Lag structures associated with the

Houck approach and the ECM approach were estimated using the Almon procedure. Lag structures were assumed to lie on a second order polynomial. Endpoint restrictions were used in conjunction with the Almon procedure. The length of the distributed lag process was determined based on the Akaike Information Criterion (AIC) and the Schwarz Information Criterion (SIC).

5. Empirical Results

The estimated coefficients and their estimated p-values associated with the Houck approach and the ECM approach for whole milk and for two percent milk for each of the seven cities are exhibited in Tables 7-10. Estimated coefficients in most cases are statistically different from zero and are in accord with a priori expectations. The level of significance chosen for this analysis is the 0.05 level. For the equations corresponding to the Houck approach, the goodness-of-fit statistics range from 0.1682 to 0.4342, and for the equations corresponding to the ECM approach, the goodness-of-fit statistics range from 0.2024 to 0.4711. The relatively low magnitudes of these R^2 statistics are attributable to the fact that the dependent variables correspond to changes in retail prices.

With the Houck approach, the number of lags associated with rising farm price variables typically is one except in the cases of Seattle (whole milk and two percent milk), Dallas (two percent milk), and St. Louis (two percent milk.) The number of lags associated with declining farm price variables also is generally one except in the cases of Chicago (whole milk) and Dallas (whole milk and two percent milk.) This finding indicates, in contrast to Kinnucan and Forker, that the time for milk prices at the retail level to adjust to either increases or decreases in milk prices at the farm level is roughly the same.

However, with the ECM approach, with the exception of Dallas (two percent milk) and Seattle (two percent milk), in agreement with Kinnucan and Forker, milk prices at the retail level adjust more slowly to decreases in milk prices at the farm level. The number of lags associated with rising farm price variables is between one and three months, most commonly one month.

The number of lags associated with declining farm price variables is between one and six months, most commonly two months.

With the Houck approach and the ECM approach, the cumulative effect on retail milk prices attributable to increases in farm milk prices exceeds the cumulative effect attributable to decreases in farm milk prices. The only exceptions are in the cases of milk prices in Dallas and St. Louis. The F-test associated with the null hypothesis that retail prices respond symmetrically to increases and decreases in farm prices (equation (3)) is rejected with the Houck approach in all cases except for St. Louis. With the ECM approach, the hypothesis of symmetry in price transmission (equation (8)) is rejected in all cases.

Additionally, we are in position to determine whether or not the error correction model statistically is superior to the Houck model. From equation (7), to carry out this statistical test, we consider the joint significance of B_2^+, B_2^-, and B_{3i} (i=1, . . . P_1). The F-statistic is the basis of this test, assuming the lag structures are the same for ΔP_{ft}^{+} and ΔP_{ft}^{-}. If the lag structures are not the same, then one may use either the Akaike Information Criterion (AIC) or Schwarz Information Criterion (SIC) to make the statistical comparison between model specifications. For whole milk, the Houck model and the error correction model are statistically equivalent. For two percent milk, the same inference holds for Atlanta, Chicago, and Dallas. However, for Seattle and St. Louis, in the case of two percent milk, the error correction model statistically is superior to the Houck model.

Elasticities of price transmission, evaluated at the sample means of the data, are exhibited in Tables 11-14. All estimated elasticities of price transmission are for less then the elasticity of price transmission of 0.9375 reported by George and King (1971). Associated with the Houck and ECM approaches, there are short-run elasticities of price transmission and long-run elasticities of price transmission for rising and falling farm prices. The long-run elasticities of price transmission are at least twice as large as the corresponding short-run elasticities of price transmission. This result holds for both increases and decreases in prices at the farm level. For rising farm prices of milk, in the short-run, the elasticities of price transmission vary from 0.037 to 0.263. In the long-run, these elasticities of price transmission range from 0.187 to 0.527. For falling farm prices of milk, in the short-run, the elasticities of price transmission vary from 0.005 to 0.166. In the long-run, these elasticities of price transmission range from 0.031 to 0.553. Kinnucan and Forker reported the elasticity of price transmission for rising farm prices of milk to be 0.274 in the short-run and 0.462 in the long-run. For falling prices of milk, they found the elasticity of price transmission to be 0.184 for the short-run and 0.330 for the long-run. Their short-run elasticities of price transmission are outside our intervals, but their long-run elasticities of price transmission are within our intervals.

Except for Dallas (whole milk and two percent milk) and St. Louis (two percent milk), elasticities of price transmission are greater for rising farm prices then for falling price prices. Thus, in most regions, consistent with Kinnucan and Forker, increases in the farm price of milk are passed through to the retail level more fully than are decreases in the farm price of milk.

6. Concluding Comments

We analyze the behavior of spatial tests of asymmetric price transmission according to the conventional Houck approach and to the von Cramon-Taubadel and Loy ECM approach. Empirical results suggest that the farm-retail price transmission process for milk is asymmetric. This result holds true for each of the seven cities considered in our analysis. In most cases, the Houck approach and the ECM approach, (where applicable) statistically are indistinguishable. The exceptions are in the case of two percent milk for Seattle and St. Louis. With the ECM approach, milk prices at the retail level adjust more slowly to decreases in milk prices and more quickly to increases in milk prices at the farm level. This conclusion is not supported by the Houck approach. Price transmission elasticities for rising farm prices generally are larger than corresponding elasticities associated with falling farm prices in most cases for both the Houck approach and the ECM approach. The short-run elasticities of price transmission for milk products are smaller in magnitude compared to those reported in the literature. The long-run elasticities of price transmission are consistent with those reported in the literature.

We recommend that in future studies of asymmetry and elasticities of price transmission that: (1) consideration be given to the ECM approach in addition to the conventional Houck approach; and (2) the analysis be conducted on a spatial basis, either by city or region in lieu of a national analysis. Our empirical results suggest that differences in inferences not only are possible but also occur by geographical area.

Table 1. Granger Causality Tests From 1994:01 to 2002:10 Based On Monthly Data of Farm and Retail Prices for Whole Milk[a]

City	Effect	Hypothesized Cause	F-statistic	P-value
Atlanta	Farm Price	Retail Price	0.65	0.5217
Atlanta	Retail Price	Farm Price	3.31	0.0406*
Boston	Farm Price	Retail Price	1.69	0.1881
Boston	Retail Price	Farm Price	0.04	0.9612
Chicago	Farm Price	Retail Price	0.55	0.5814
Chicago	Retail Price	Farm Price	4.55	0.0219*
Dallas	Farm Price	Retail Price	0.92	0.4010
Dallas	Retail Price	Farm Price	9.00	0.0003*
Hartford	Farm Price	Retail Price	0.04	0.9652
Hartford	Retail Price	Farm Price	0.75	0.4755
Seattle	Farm Price	Retail Price	0.13	0.8799
Seattle	Retail Price	Farm Price	6.28	0.0027*
St. Louis	Farm Price	Retail Price	0.35	0.3474
St. Louis	Retail Price	Farm Price	22.69	0.0000*

* indicates statistical significance at the 0.05 level.

[a] The null hypothesis is that one series does not Granger cause another. The Granger causality tests use a lag length of two months.

Table 2. Granger Causality Tests From 1994:01 to 2002:10 Based On Monthly Data of Farm and Retail Prices for Two Percent Milk[a]				
City	**Effect**	**Hypothesized Cause**	**F-statistic**	**P-value**
Atlanta	Farm Price	Retail Price	0.19	0.8308
Atlanta	Retail Price	Farm Price	3.36	0.0387*
Boston	Farm Price	Retail Price	1.25	0.2898
Boston	Retail Price	Farm Price	0.42	0.6607
Chicago	Farm Price	Retail Price	1.03	0.3580
Chicago	Retail Price	Farm Price	10.79	0.0001*
Dallas	Farm Price	Retail Price	0.43	0.6536
Dallas	Retail Price	Farm Price	5.92	0.0037*
Hartford	Farm Price	Retail Price	0.18	0.8348
Hartford	Retail Price	Farm Price	0.72	0.4899
Seattle	Farm Price	Retail Price	0.55	0.5792
Seattle	Retail Price	Farm Price	6.09	0.0032*
St. Louis	Farm Price	Retail Price	2.02	0.1378
St. Louis	Retail Price	Farm Price	32.65	0.0000*

* indicates statistical significance at the 0.05 level.

[a] The null hypothesis is that one series does not Granger cause another. The Granger causality tests use a lag length of two months.

Table 3. Descriptive Statistics of Whole Milk Prices at the Farm and Retail Level of the Marketing Channel					
Farm Prices – Whole Milk					
City	**Mean**	**Median**	**Standard Deviation**	**Minimum**	**Maximum**
Atlanta	1.41	1.38	0.14	1.13	1.83
Boston	1.46	1.47	0.12	1.25	1.78
Chicago	1.36	1.32	0.14	1.15	1.75
Dallas	1.37	1.34	0.12	1.16	1.76
Hartford	1.45	1.47	0.12	1.24	1.77
Seattle	1.28	1.26	0.13	1.05	1.66
St. Louis	1.37	1.35	0.14	1.13	1.75
Retail Prices – Whole Milk					
City	**Mean**	**Median**	**Standard Deviation**	**Minimum**	**Maximum**
Atlanta	2.67	2.69	0.42	1.98	3.29
Boston	2.66	2.61	0.23	2.33	3.08
Chicago	2.99	2.95	0.26	2.66	3.49
Dallas	2.63	2.62	0.28	2.22	3.22
Hartford	2.68	2.68	0.23	2.38	3.10
Seattle	3.29	3.18	0.30	2.92	3.92
St. Louis	2.80	2.92	0.30	2.24	3.26

Table 4. Descriptive Statistics of Two Percent Milk Prices at the Farm and Retail Level of the Marketing Channel					
Farm Prices – Two Percent Milk					
City	**Mean**	**Median**	**Standard Deviation**	**Minimum**	**Maximum**
Atlanta	1.29	1.25	0.12	1.03	1.68
Boston	1.33	1.33	0.10	1.14	1.63
Chicago	1.23	1.20	0.13	0.91	1.60
Dallas	1.24	1.21	0.11	0.96	1.61
Hartford	1.32	1.32	0.10	1.13	1.63
Seattle	1.15	1.14	0.12	0.94	1.51
St. Louis	1.24	1.22	0.13	0.96	1.60
Retail Prices – Two Percent Milk					
City	**Mean**	**Median**	**Standard Deviation**	**Minimum**	**Maximum**
Atlanta	2.67	2.69	0.42	1.98	3.22
Boston	2.54	2.47	0.29	2.14	3.05
Chicago	2.78	2.72	0.37	2.26	3.39
Dallas	2.63	2.62	0.28	2.12	3.22
Hartford	2.61	2.56	0.27	2.25	3.07
Seattle	3.17	3.09	0.30	2.72	3.82
St. Louis	2.74	2.85	0.31	2.16	3.23

Table 5. Empirical Results of the Johansen Cointegration Tests for Farm Prices and Retail Prices of Whole Milk

City	Hypothesized Number of Cointegrated Equation	Trace Statistic	P-Value	Maximal Eigenvalue Statistic	P-Value
Atlanta	None	20.79	0.0072*	18.38	0.0106*
	At most 1	2.41	0.1202	2.41	0.1202
Boston	None	8.23	0.4407	8.20	0.3581
	At most 1	0.03	0.8674	0.03	0.8674
Chicago	None	19.93	0.0100*	17.85	0.0129*
	At most 1	2.07	0.1498	2.07	0.1498
Dallas	None	23.95	0.0021*	22.46	0.0021*
	At most 1	1.49	0.2215	1.49	0.2215
Hartford	None	6.95	0.5826	6.84	0.5076
	At most 1	0.11	0.7378	0.11	0.7378
Seattle	None	12.00	0.1568	11.25	0.1420
	At most 1	0.75	0.3867	0.75	0.3867
St. Louis	None	11.86	0.1636	14.26	0.0742
	At most 1	2.71	0.0992	2.71	0.0992

* EVIEWS 5.0 was the statistical package employed to conduct these cointegration rank tests. The intercept (no trend) option with four lags was used in conjunction with these tests. The level of significance chosen for this analysis was 0.05.

Table 6. Empirical Results of the Johansen Cointegration Rank Tests for Farm Prices and Retail Prices of Two Percent Milk					
City	**Hypothesized Number of Cointegrated Equation**	**Trace Statistic**	**P-Value**	**Maximal Eigenvalue Statistic**	**P-Value**
Atlanta	None	31.43	0.0001*	28.99	0.0001*
	At most 1	2.44	0.1178	2.44	0.1178
Boston	None	14.37	0.0733	13.85	0.0580
	At most 1	0.52	0.4715	0.52	0.4715
Chicago	None	26.92	0.0006*	24.94	0.0007*
	At most t 1	1.98	0.1587	1.98	0.1587
Dallas	None	23.28	0.0027*	21.89	0.0026*
	At most 1	1.39	0.2378	1.39	0.2378
Hartford	None	11.80	0.1668	11.53	0.1294
	At most 1	0.26	0.6071	0.26	0.6071
Seattle	None	18.10	0.0198*	17.25	0.0163*
	At most 1	0.85	0.3568	0.85	0.3568
St. Louis	None	22.00	0.0045*	18.43	0.0103*
	At most 1	3.57	0.0589	3.57	0.0589

* EVIEWS 5.0 was the statistical package employed to conduct these cointegration rank tests. The intercept (no trend) option with four lags was used in conjunction with these tests. The level of significance chosen for this analysis was 0.05.

Table 7. Empirical Results of the Houck Procedure for Whole Milk							
	Atlanta	**Boston**	**Chicago**	**Dallas**	**Hartford**	**Seattle**	**St. Louis**
Intercept	-0.003674[a] (0.5553)[b]	-0.006278 (0.1315)	-0.006940 (0.5363	0.013621 (0.1418)	-0.003446 (0.4544)	-0.004268 (0.6176)	0.008727 (0.2678)
ΔP^{+}_{ft} **(SR^{+})**	0.27510 (0.0014)	0.45386 (0.0000)	0.44294 (0.0001)	0.23056 (0.0338)	0.41118 (0.0000)	0.22775 (0.0027)	0.27159 (0.0015)
ΔP^{+}_{ft-1}	0.27510 (0.0014)	0.45386 (0.0000)	0.44294 (0.0001)	0.23056 (0.0338)	0.41118 (0.0000)	0.30366 (0.0027)	0.27159 (0.0015)
ΔP^{+}_{ft-2}	--	--	0.16940 (0.0012)	0.21221 (0.0000)	--	0.22775 (0.0027)	--
LR^{+}	0.55019 (0.0014)	0.90773 (0.0000)	0.88589 (0.0001)	0.46112 (0.0338)	0.82235 (0.0000)	0.75915 (0.0027)	0.54317 (0.0015)
ΔP^{-}_{ft} **(SR^{-})**	0.04957 (0.2215)	0.11877 (0.0203)	0.16940 (0.0012)	0.21221 (0.0000)	0.13221 (0.0069)	0.14008 (0.0237)	0.28594 (0.0000)
ΔP^{-}_{ft-1}	0.04957 (0.2215)	0.11877 (0.0203)	0.22587 (0.0012)	0.28294 (0.0000)	0.13221 (0.0069)	0.14008 (0.0237)	0.28594 (0.0000)
ΔP^{-}_{ft-2}	--	--	0.16940 (0.0012)	0.21221 (0.0000)	--	--	--
LR^{-}	0.09914 (0.2215)	0.23754 (0.0203)	0.56467 (0.0012)	0.70738 (0.0000)	0.26442 (0.0069)	0.28015 (0.0237)	0.57188 (0.0000)
AR(1)	--	-0.222235 (0.0228)	--	-.151807 (0.1359)	--	-0.369191 (0.0002)	--
AR(2)	--	-0.358957 (0.0228)	--	--	--	--	--
R^2	0.2115	0.3537	0.2496	0.2157	0.3402	0.2113	0.3325
DW	2.05	2.10	2.10	2.05	2.17	2.01	2.24
SIC	-3.2477	-3.2955	-2.1980	2.3026	-3.8033	-2.4033	-2.8426
AIC	-3.3240	-3.4241	-2.2747	2.4055	-3.8796	-2.5062	-2.9189

[a] Parameter estimate
[b] p-value

Table 8. Empirical Results of the Houck Procedure for Two Percent Milk							
	Atlanta	**Boston**	**Chicago**	**Dallas**	**Hartford**	**Seattle**	**St. Louis**
Intercept	-0.002636[a] (0.6576)[b]	-0.007404 (0.1422)	-0.006115 (0.5837)	0.017055 (0.1170)	-0.004233 (0.3340)	-0.000960 (0.9134)	0.01078 (0.0990)
ΔP^{+}_{ft} **(SR+)**	0.28877 (0.0000)	0.43083 (0.0000)	0.46785 (0.0000)	0.07757 (0.1610	0.38266 (0.0000)	0.19077 (0.0053)	0.21396 (0.0000)
ΔP^{+}_{ft-1}	0.28877 (0.0000)	0.43083 (0.0000)	0.46785 (0.0000)	0.11635 (0.1610)	0.38266 (0.0000)	0.25437 (0.0053)	0.28528 (0.0000)
ΔP^{+}_{ft-2}	--	--	--	0.11635 (0.1610)	--	0.19077 (0.0053)	0.21396 (0.0000)
ΔP^{+}_{ft-3}	--	--	--	0.07757 (0.1610)	--	--	--
LR+	0.57753 (0.0000)	0.86165 (0.0000)	0.93570 (0.0000)	0.38785 (0.1610)	0.76532 (0.0000)	0.63592 (0.0053)	0.71321 (0.0000)
ΔP^{-}_{ft} **(SR-)**	0.03257 (0.4227)	0.11671 (0.0574)	0.26141 (0.0009)	0.22394 (0.0001)	0.13135 (0.0191)	0.16906 (0.0237)	0.38307 (0.0000)
ΔP^{-}_{ft-1}	0.03257 (0.4227)	0.1167) (0.0574)	0.26141 (0.0009)	0.29858 (0.0001)	0.13135 (0.0191)	016906 (0.0237)	0.38307 (0.0000)
ΔP^{-}_{ft-2}	--	--	--	0.22394 (0.0001)	--	--	--
LR-	0.06514 (0.4227)	0.23342 (0.0574)	0.52281 (0.0009)	0.74647 (0.0001)	0.26270 (0.0191)	0.33811 (0.0237)	0.76614 (0.0000)
AR(1)	--	-0.216414 (0.0223)	--	--	--	-0.416440 (0.0000)	-0276731 (0.0054)
AR(2)	--	-0.421606 (0.0000)	--	--	-0.349744 (0.0003)	--	--
R^2	0.1826	0.3643	0.2784	0.1682	0.3877	0.2368	0.4342
DW	2.01	2.21	2.17	2.25	2.29	2.03	2.07
SIC	-3.3355	-3.0374	-2.1111	-2.2891	-3.5327	-2.1024	-2.7567
AIC	-3.4113	-3.1653	-2.1870	-2.3659	-3.6613	-2.2047	-2.8590

[a] Parameter estimate
[b] p-value

Table 9. Error Correction Model Results for Whole Milk			
	Atlanta	**Chicago**	**Dallas**
Intercept	-0.002137[a] (0.7603)[b]	-0.005022 (0.6858)	0.020109 (0.0908)
ΔP^{+}_{ft} **(SR^{+})**	0.31739 (0.0000)	0.48246 (0.0001)	0.32577 (0.0097)
ΔP^{+}_{ft-1}	0.31739 (0.0000)	0.48246 (0.0001)	0.32477 (0.0097)
LR+	0.63478 (0.0000)	0.96492 (0.0001)	0.65153 (0.0097)
ΔP^{-}_{ft} **(SR^{-})**	0.03149 (0.1449)	0.1713 (0.0023)	0.2479 (0.0000)
ΔP^{-}_{ft-1}	0.04723 (0.1449)	0.2284 (0.0023)	0.33054 (0.0000)
ΔP^{-}_{ft-2}	0.04723 (0.1449)	0.1713 (0.0023)	0.2479 (0.0000)
ΔP^{-}_{ft-3}	0.03149 (0.1449)	--	--
LR-	0.15744 (0.1449)	0.57171 (0.0023)	0.82635 (0.0000)
ECT^{+}_{t-1}	-0.127414 (0.3294)	0.012534 (0.9226)	1.31208 (0.0945)
ECT^{-}_{t-1}	-0.125466 (0.3595)	0.123136 (0.3607)	1.488138 (0.0514)
ΔP_{rt-1}	--	-0.137828 (0.2844)	-1.567282 (0.0505)
ΔP_{rt-2}	-0.216006 (0.0733)	--	1.22297 (0.0965)
ΔP_{rt-3}	-0.165305 (0.0876)	--	--
ΔP_{rt-4}	--	--	--
R2	0.2588	0.2626	0.2573
DW	1.87	1.980	2.06
F-statistic For Model Superiority	Lag structure different	0.5695 (0.6364)	1.9373 (0.1104)
AIC	-3.2877	-2.2339	-2.4122
SIC	-3.1075	-2.0805	-2.2332

[a] Parameter estimate
[b] p-value

Table 10. Error Correction Model Results for Two Percent Milk					
	Atlanta	**Chicago**	**Dallas**	**Seattle**	**St. Louis**
Intercept	-0.001856[a] (0.8184)[b]	-0.005114 (0.7017)	0.024648 (0.0577)	-0.013962 (0.3009)	0.020099 (0.0333)
ΔP^{+}_{ft} **(SR^{+})**	0.31075 (0.0000)	0.4937 (0.0000)	0.09969 (0.0772)	0.26451 (0.0052)	0.2739 (0.0000)
ΔP^{+}_{ft-1}	0.31075 (0.0000)	0.4937 (0.0000)	0.14953 (0.0772)	0.35266 (0.0052)	0.3652 (0.0000)
ΔP^{+}_{ft-2}	--	--	0.14953 (0.0772)	0.26451 (0.0000)	0.2739 (0.0000)
ΔP^{+}_{ft-3}	--	--	0.09969 (0.0772)	--	--
LR+	0.6215 (0.0000)	0.9874 (0.0000)	0.49843 (0.0772)	0.88171 (0.0052)	0.91301 (0.0000)
ΔP^{-}_{ft} **(SR^{-})**	0.01105 (0.4209)	0.19443 (0.0012)	0.24388 (0.0000)	0.19699 (0.0373)	0.25545 (0.0000)
ΔP^{-}_{ft-1}	0.01894 (0.4209)	0.25923 (0.012)	0.32518 (0.0000)	0.19699 (0.0373)	0.38317 (0.0000)
ΔP^{-}_{ft-2}	0.02368 (0.4209)	0.19443 (0.0012)	0.24388 (0.0000)	--	0.38317 (0.0000)
ΔP^{-}_{ft-3}	0.02526 (0.4209)	--	--	--	0.25545 (0.0000)
ΔP^{-}_{ft-4}	0.02368 (0.4209)	--	--	--	--
ΔP^{-}_{ft-5}	0.01894 (0.4209)	--	--	--	--
ΔP^{-}_{ft-6}	0.01105 (0.4209)	--	--	--	--
LR-	0.1326 (0.4209)	0.64808 (0.0012)	0.81294 (0.0000)	0.39399 (0.0373)	1.27723 (0.0000)
ECT^{+}_{t-1}	-0.029021 (0.8185)	-0.082744 (0.4599)	0.046736 (0.6976)	0.125001 (0.3158)	-0.274774 (0.0363)
ECT^{-}_{t-1}	-0.75598 (0.5772)	-0.120677 (0.3332)	0.221971 (0.0978)	-0.125171 (0.3674)	-0.398899 (0.0000)
ΔP_{rt-1}	--	--	-0.262951 (0.0602)	-0.428779 (0.0158)	--
ΔP_{rt-2}	--	-0.125292 (0.2344)	--	--	-0.548005 (0.0000)
ΔP_{rt-3}	-0.204251 (0.0431)	--	--	0.13835 (0.1735)	--
F-statistic for model superiority	Lag structure different	Lag structure different	1.3841 (0.2523)	6.3396 (0.0001)	Lag structure different
R2	0.2304	0.2920	0.2024	0.2715	0.4711
DW	2.04	1.99	2.08	1.94	2.01
AIC	-3.3749	-2.1275	-2.3495	-2.1819	-2.8875
SIC	-3.2196	-1.9740	-2.1960	-2.0018	-2.7341

[a] Parameter Estimate

[b] p-value

Table 11. Elasticities of Price Transmission for Whole Milk with the Houck Approach							
	Atlanta	**Boston**	**Chicago**	**Dallas**	**Hartford**	**Seattle**	**St. Louis**
EPT_POS_SR[a]	0.1527	0.2637	0.2091	0.1247	0.2360	0.0923	0.1386
EPT_NEG_SR[b]	0.0258	0.0630	0.0737	0.1077	0.0693	0.0517	0.1306
EPT_POS_LR[c]	0.3054	0.5275	0.4182	0.2494	0.4720	0.3077	0.2772
EPT_NEG_LR[d]	0.0516	0.1261	0.2459	0.3592	0.1386	0.1034	0.2613

[a] EPT_POS_SR short-run elasticity of price transmission for rising farm prices
[b] EPT_NEG_SR short-run elasticity of price transmission for falling farm prices
[c] EPT_POS_LR long-run elasticity of price transmission for rising farm prices
[d] EPT_NEG_LR long-run elasticity of price transmission for falling farm prices

Table 12. Elasticities of Price Transmission for Two Percent Milk with the Houck Approach							
	Atlanta	**Boston**	**Chicago**	**Dallas**	**Hartford**	**Seattle**	**St. Louis**
EPT_POS_SR[a]	0.1451	0.2377	0.2148	0.0375	0.2046	0.0717	0.1008
EPT_NEG_SR[b]	0.1059	0.0596	0.1135	0.1048	0.0650	0.0597	0.1660
EPT_POS_LR[c]	0.2902	0.4754	0.4297	0.1878	0.4092	0.2390	0.3360
EPT_NEG_LR[d]	0.0319	0.1193	0.2270	0.3494	0.1301	0.1194	0.3321

[a] EPT_POS_SR short-run elasticity of price transmission for rising farm prices
[b] EPT_NEG_SR short-run elasticity of price transmission for falling farm prices
[c] EPT_POS_LR long-run elasticity of price transmission for rising farm prices
[d] EPT_NEG_LR long-run elasticity of price transmission for falling farm prices

Table 13. Elasticities of Price Transmission for Whole Milk With the ECM Approach			
	Atlanta	**Chicago**	**Dallas**
EPT_POS_SR[a]	0.1761	0.2278	0.1762
EPT_NEG_SR[b]	0.0164	0.0746	0.1258
EPT_POS_LR[c]	0.3523	0.4556	0.3524
EPT_NEG_LR[d]	0.0820	0.2486	0.4196

[a] EPT_POS_SR short-run elasticity of price transmission for rising farm prices
[b] EPT_NEG_SR short-run elasticity of price transmission for falling farm prices
[c] EPT_POS_LR long-run elasticity of price transmission for rising farm prices
[d] EPT_NEG_LR long-run elasticity of price transmission for falling farm prices

Table 14. Elasticities of Price Transmission for Two Percent Milk With the ECM Approach					
	Atlanta	**Chicago**	**Dallas**	**Seattle**	**St. Louis**
EPT_POS_SR[a]	0.1561	0.2267	0.0482	0.0994	0.1290
EPT_NEG_SR[b]	0.0054	0.0844	0.1141	0.0695	0.1107
EPT_POS_LR[c]	0.3123	0.4534	0.2414	0.3315	0.4301
EPT_NEG_LR[d]	0.0650	0.2814	0.3805	0.1391	0.5536

[a] EPT_POS_SR short-run elasticity of price transmission for rising farm prices
[b] EPT_NEG_SR short-run elasticity of price transmission for falling farm prices
[c] EPT_POS_LR long-run elasticity of price transmission for rising farm prices
[d] EPT_NEG_LR long-run elasticity of price transmission for falling farm prices

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