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Abstract:

Retail milk price responses to farm price changes were analyzed for Boston, Massachusetts, and Hartford, Connecticut. Prior research concluded asymmetries did not exist in the response of retail fluid milk prices to changes in farm prices. This study finds transmission rates were greater for the Compact period (100 – 120 percent) than the Pre-Compact period (66 – 88 percent). Short-run asymmetries were apparent. Retail prices responded rapidly to farm price increases, but slowly to farm price decreases. This study also finds evidence of long-run asymmetry. When equivalent farm price increases and decreases occur, retail prices do not return to the same levels that were observed before the price changes. Such long-run asymmetry was not observed in prior empirical studies of retail prices in the Northeast.

Keywords: asymmetry, fluid milk, retail prices, farm-to-retail price margins.

EconLit Classification: Q110, Q130, L110.

Introduction

Northeast farm and retail fluid milk prices have captured a great deal of attention for nearly a decade (see, for example, Kilman, 2003, or Mohl, 2004). This is primarily due to the operation of the Northeast Dairy Compact (Compact) from July 1, 1997, to September 30, 2001. That program established a farm price floor at $16.94 per hundred weight for fluid milk sold in New England. In the policy debate that surrounded the advent and demise of the Compact, a critical economic issue was the rate of price transmission between raw and retail fluid milk prices. When the Compact was implemented, a critical question was whether consumers would pay more or less than the increase in the raw milk price caused by the Compact. When the Compact was dismantled with its consequent reduction in raw prices, a critical question was who would benefit? Would the price reduction be passed on to consumers? Research devoted to analyzing the impacts of the Compact on retail prices offered scenarios from a limited pass through (Lass, et al., 2001) to a pass through well in excess of 100% (Bailey, 2000). Those and other studies that were central to the Compact policy debate were based on limited data because they were completed either just prior to, or during, the Compact era. The rate of price transmission and the Compact's impact on price transmission remains an unsettled issue. Now that data for the full Compact period are available, one can revisit and reanalyze the price transmission question in a more complete fashion.

One issue that remains a concern is whether farm price increases and decreases had asymmetric effects on retail fluid milk prices (see GAO, 2004, for a review). Kinnucan and Forker (1987) investigated asymmetric price effects in the US dairy industry by incorporating Houck's (1977) method of estimating non-reversible functions into the basic mark-up price model (Heien, 1980). They found that rising farm prices were incorporated rapidly in retail prices, while retail prices were slow to adjust to decreases in farm prices, effects referred to as *short-run* asymmetries. They also found that falling farm prices were not incorporated in retail prices to the same degree as rising farm prices. Holding all other factors constant, when the farm price first increased and then fell back to its previous level, the retail price would fail to return to its previous level resulting in *long-run* asymmetry.

Lass, et al. (2001), and Frigon, et al. (1999), investigated possible asymmetries in the Northeast. Lass, et al. (2001), concluded that a *long-run* asymmetric response of retail fluid milk prices to changes in farm prices did not exist in models for Boston, Massachusetts, and Hartford, Connecticut. Applying the methods of Kinnucan and Forker (1987) to time series data from 1982 through June 1996, they found that retail prices increased sharply and immediately to increases in the farm price. They also found that an equivalent decrease in the farm price would cause a more measured and steady decline, but that (*ceteris paribus*) these effects would result in the retail price returning to the same level observed prior to these changes after all lagged effects were complete. Thus, their research concluded that, while the speeds of adjustment certainly differed, there was not sufficient evidence to conclude that *long-run* asymmetry existed. Frigon, et al. (1999), reached similar conclusions: that the speeds of adjustment were different for rising versus falling farm prices, but that evidence of *long-run* asymmetry did not exist. Inclusion of concentration ratios did not have statistically important effects on the results.

Another issue is whether market channel firms changed their pricing conduct in response to the implementation of the Compact. Cotterill (2003) has argued that the structure of the dairy industry has changed through the 1990s, particularly in the period just prior to the Compact debate and institution, and that these changes have continued through the late 1990s and into the new millennium. Structural changes may lead to new lessons in retail price responses to changing input costs. Figure 1 shows changes that have occurred in farm and retail prices from 1990 through September 2001, the period of this study. After institution of the Compact, a “floor” was established for the farm price of milk as indicated on the graph. The Class I price of milk in the Northeast was below the minimum price established by the Compact during much of the period, with a few exceptions in mid-to-late 1998, 1999 and 2001. Changes in the farm-to-retail price spread are difficult to discern in Figure 1 through the mid 1990s. However, immediately following institution of the Compact, a distinct increase in the farm to retail price spread can be seen despite the limited increases that occurred in farm prices.

This study investigates whether there are new lessons to be learned from new data that are now available for the Compact period. Previous analyses of price asymmetry in the Northeast were limited to estimation with data through the mid-1990s. Time series data for the period 1990 through the life of the Northeast Interstate Dairy Compact in September of 2001 are used to estimate the same models of retail price response to farm prices. Sufficient data exist to estimate models for the Pre-Compact period as well as the Compact period. The Compact, while not a focus of this research, provides a convenient and theoretically logical point at which to separate the sample of data. Comparisons are made directly to the results of Lass, et al. (2001). The results of this study do suggest that with new data we find new lessons.

Model of Retail Price Response

The Kinnucan and Forker (1987) (KF) results were considered important for anyone analyzing farm-to-retail price transmissions. The KF model as employed by Lass, et al. (2001), is followed closely here in order to make direct comparisons to these prior results.[1] In that modification of the Heien mark-up price model, farm prices are separated into rising and falling categories. Rising and falling farm prices are included separately in the model to allow for possibly differential effects on retail prices. Dynamic processes of retail price adjustments to rising versus falling farm prices are captured by inclusion of current and lagged values of farm prices. Following Lass, et al. (2001), the basic mark-up price model is:

$$(1) \qquad R_t = \delta_0 t + \sum_{i=0}^{2} \pi_i^R FR_{t-i} + \sum_{i=0}^{2} \pi_i^F FF_{t-i} + \beta P_t + e_t \;;$$

where R_t is the accumulated change in retail price, t is a time trend variable,

$$FR_t = \sum_{i=0}^{t-2} Max(\Delta F_{t-i}, 0)$$

measures the accumulated increases in farm price up to period t, $\Delta F_t = F_t - F_{t-1}$,

$$FF_t = \sum_{i=0}^{t-2} Min(\Delta F_{t-i}, 0)$$

measures the accumulated decreases in farm price up to period t, and P is accumulated price changes for marketing costs. There are few theoretical arguments to use in specifying lag lengths. Lass, et al. (2001), concluded that inclusion of the current farm price increases and decreases as well as one-month and two-month lagged values worked best through investigations using national data.

[1] Lyon and Thompson (1993) compared four common specifications, including the basic price mark-up model, and were unable to distinguish among them based on non-nested hypothesis tests.

To determine whether price asymmetry exists in retail milk pricing in the Boston and Hartford markets used in this study, hypothesis tests were conducted on both individual parameters and the aggregates of rising and falling parameters. In particular, we test the following null hypotheses:

$$(2) \qquad H_0: \ \pi_i^R = \pi_i^F \ ; \qquad H_a: \ \pi_i^R \neq \pi_i^F \quad \textit{for lags } i = 0, 1, 2 \ .$$

$$H_0: \ \sum_{i=0}^{2} \pi_i^R = \sum_{i=0}^{2} \pi_i^F \ ; \quad H_a: \ \sum_{i=0}^{2} \pi_i^R \neq \sum_{i=0}^{2} \pi_i^F \ .$$

The first hypotheses are tests of whether the speeds of adjustment are equivalent for rising versus falling farm prices, sometimes referred to as a test for *short-run* asymmetric price transmission. For example, as has been found previously (Kinnucan and Forker, 1987; Lass, et al., 2001; Frigon, et al., 1999), suppose the estimated current farm price increase parameter is statistically greater than the estimated current farm price decrease parameter. The conclusion would be that retail prices rise more rapidly than they fall in response to equivalent farm price increases and decreases, providing statistical evidence of *short-run* asymmetric response. The second hypothesis test will provide statistical evidence about whether retail prices return to the same level after equivalent farm price increases and decreases. All lagged effects are included to complete the effects of equivalent price increases and decreases, a process that is completed within a period of three months. The second hypothesis is referred to as a test for *long-run* price transmission asymmetry. Rejection of either null hypothesis, or both, will constitute statistical evidence of asymmetric farm-to-retail price transmission in the New England market, either in the form of *short-run* speed of adjustment differences, or in the form of *long-run* retail price responses to equivalent farm price increases and decreases.

Data

Monthly time-series data were gathered for the period January 1982 – September 2001 for the New England region. The data set is exactly that data set used by Lass, et al. (2001), but has also been extended through the period in which the Northeast Interstate Dairy Compact was in effect. The USDA Agricultural Marketing Service (2005b) (AMS) retail fluid milk price series for Boston, Massachusetts, and Hartford, Connecticut, were used to provide a consistent series of retail price data for retail fluid milk prices in the New England market. Changes in retail prices were determined from this monthly series and a variable measuring the accumulated changes was created for use as the dependent variable in estimation (equation (1)).

Our concern is the effect of farm prices on retail fluid milk prices. Thus, the appropriate farm price of milk is the Class I price for the New England market (Suffolk County, Boston). Class I price data were also available from the USDA Agricultural Marketing Service (2005a). The Class I price represents the cost of farm milk as an input for the fluid milk processing industry. Changes in the Class I price were divided into increases and decreases and summed across time to create the accumulated increase and decrease variables used in estimation of equation (1).

The USDA's Economic Research Service provided marketing cost indexes.[2] These indexes represent producer price indexes for labor, packaging, and transportation inputs used in processing and marketing. A composite marketing cost index was also available that represents a weighted aggregate index of the three components. Given the high degree of collinearity between the individual components, estimation and

[2] Howard Elitzak of the USDA, Economic Research Service, provided the market cost indexes.

identification of individual effects is difficult when all three are included in the model. By using the composite index, estimation problems may be avoided without encountering the problems associated with omitting important variables. The final aggregate marketing cost variable represents accumulated changes. The variable was created in the same manner as other accumulated change variables by summing changes in the marketing cost index ($\Delta P_t = P_t - P_{t-1}$) over the time series.

Results

The KF mark-up price model was applied to estimate relationships between farm and retail milk prices in two Northeast cities, Boston, Massachusetts, and Hartford, Connecticut. The dependent variables were the accumulated changes in retail milk prices for each city. Independent variables included accumulated increases and accumulated decreases in the farm price of milk as measured by the Class I price for the Northeast Federal Market and an index of marketing costs obtained form the USDA Economic Research Service. During the Compact years (July 1997 through September 2001) the farm price of milk was the Class I price or the Compact minimum of $16.94 per hundredweight, whichever was greater. All data gathered were monthly prices or indexes.

Lass, et al. (2001), used national data to specify their models, thereby avoiding issues surrounding post-data model construction. We follow their specification, which allows direct comparisons to their results. Lass, et al. (2001), used a time-series of data that extended from January 1982 through June 1996 for estimation. A number of policy changes occurred during the 1980s that may have affected dairy production. Adanu (1999) tested for structural change and concluded there was no evidence of structural change through the 1980s. However, processing and retail industry changes occurred during the 1990s that may have affected retail prices (Cotterill, 2003). Given sufficient data available to estimate retail price models for separate periods before and after the Compact, it makes sense to avoid potential issues surrounding the use of a longer time series for estimation of the initial model. The analyses below will focus on models estimated for the two separate time periods, one prior to institution of the Compact, and another for the Compact period.[3] Specifically, data from January 1990 through September 2001 are used for the analyses in this study. In addition to the logical sample separation due to institution of the Compact, the variables of the two time periods were found to have different time-series properties making sample separation an empirical necessity as well. These issues are discussed before presentation of the KF model results.

Stationary Time Series and Cointegration Tests

All monthly time-series data for accumulated retail price changes, accumulated farm price increases, accumulated farm price decreases, and accumulated marketing cost changes were tested to determine whether they were stationary. Unit-root tests were conducted and indicated that all variables in the Pre-Compact period, January 1990 through June 1997, were non-stationary. All variables in the Compact period, July 1997 through September 2001, were non-stationary as well. The series for the Compact period (July, 1997 – September, 2001) were also cointegrated.[4] Prior to the Compact, retail price

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[3] Initially, a single model was estimated for the combined Pre-Compact (January 1990 through June 1997) and Compact (July 1997 through September 2001) periods. A hypothesis test was conducted to determine whether structural change occurred between the Pre-Compact and Compact periods. A test of the null hypothesis of no structural change was conducted as an F-test of parameter equality for the two periods. The calculated F-statistic of 3.16 was greater than the critical value: $F(0.01, 6, 114) = 2.96$

[4] A modified Dickey-Fuller test was applied to determine whether the series were cointegrated. The structural model was estimated by least squares and the residuals were used to estimate the following relationship:

changes, farm price increases, farm price decreases and marketing cost increases were not cointegrated. Thus, linear methods applied to the variables in levels for the Pre-Compact period may result in spurious results. These tests suggest two separate methods be applied to estimate the KF asymmetric response models. For the Pre-Compact period, all series were differenced, which resulted in stationary series.[5] Because the series for the Compact period were also cointegrated, the data series were used in levels to estimate the effects of changes in the farm price of milk and marketing costs on the retail price of milk.

Models for Boston and Hartford were estimated using maximum likelihood methods to correct for potential autocorrelation. The errors of the differenced aggregate retail price increases for the Pre-Compact period were not found to be autocorrelated, while the Compact period data were found to be autocorrelated. The maximum likelihood results are presented for all four models estimated.

Retail Price Models: Boston and Hartford

Table 1 shows the estimated parameters for Boston retail milk price models for the Pre-Compact period and the Compact period. Results for Boston Pre-Compact and Compact models support the findings of Lass, et al. (2001). Farm-to-retail milk price transmission can be characterized as rapid upward adjustments of retail prices in response to farm price increases. The greatest increases occurred for current month farm price changes and these effects were statistically significant at the one percent level of significance. Effects of price increases in subsequent months were much lower and

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$$\Delta e_t = e_t - e_{t-1} = (\rho - 1)\, e_{t-1} + v_t ,$$

where e_t are the OLS residuals. If $\rho = 1$, then the series is non-stationary. Thus, the test is of the null hypothesis $(\rho - 1) = 0$ using a modified t-test (Engle and Yoo, 1987).

[5] For all series, a first difference was found to be sufficient.

suggested both positive and negative effects due to farm price increases. These lagged effects were not statistically different from zero.

Responses of retail milk prices to decreases in the farm price were not statistically important for the Pre-Compact model. The estimated effects for current and one-month lagged farm price decreases were virtually equal and suggest a much slower and even adjustment process than was estimated for farm price increases. For the Compact model, farm price decreases led to a statistically significant current month decreases in retail prices. However, the one-month lagged effect of a farm price decrease resulted in a subsequent upward correction in retail prices, also statistically significant.

Effects of marketing cost increases have the expected positive sign in each period. These effects are both more substantial and are statistically important during the Compact period.

Estimates for the Pre-Compact and Compact models are shown in Table 2 for Hartford. Similar to the results for Boston, increases in the farm price of milk had strong positive estimated current month effects on Hartford retail milk prices. The estimated effects were smaller in magnitude in subsequent months (lagged effects). There are estimated negative adjustments for the one-month lag (Pre-Compact model) followed by a subsequent increase for the two-month lag. For the Compact period, the estimated current period and one-month lag effects lead to substantial increases in retail price. Estimated current month effects of farm price decreases were also statistically significant, but lower in magnitude than the estimated effects of farm price increases. All lagged effects for farm price decreases resulted in lower retail prices, although these estimated effects were not statistically significant.

Perhaps the most effective way to convey the estimated asymmetric retail price responses is to view the accumulated current and lagged effects for equivalent farm price increases and decreases, holding all other effects constant (partial effects). The results of Lass, et al. (2001), are used for comparisons and are shown in Figure 2. An initial retail price of $2.50 per gallon is assumed. In the second period (second month), the farm price of milk is increased by $1.162 per hundredweight or, equivalently, $0.10 per gallon. No further farm price increases are assumed in order to complete an illustration of the estimated lagged effects of the farm price increase. A current period retail price increase of $0.082 per gallon occurs, followed by adjustments downwards. The accumulated increase (after three months) in retail price due to the farm price increase was $0.063 in Boston. While retail prices followed a different path of adjustment in Hartford, the net effect of a $0.10 per gallon increase in the farm price was a similar $0.058 per gallon increase in the retail price of milk. Thus, transmission rate for the price increase was about 60 percent.

Now let's analyze the impact of an equivalent decrease in the farm price of milk. In month five, after all farm price increase effects were complete, the farm price was reduced by an equivalent $0.10 per gallon. No further farm price decreases were made. Boston retail prices declined in response to current period and one-month lagged farm price decreases, and these two effects were approximately the same. After the effects of the farm price decrease were completed, the Boston retail price returned to the same level ($2.500 per gallon) as before the farm price was changed. While retail prices in Hartford followed a different path, they also returned to nearly the same level; the final Hartford retail milk price was $2.514 per gallon. The difference in retail price estimated for

Hartford following equivalent increases and decreases was not found to be statistically different.

Figure 3 illustrates the partial effects on Boston retail prices for the same farm price changes using the results from this study. In the initial month, we again assume the retail price is $2.50 per gallon. The farm price of milk is increased in the second month by $1.16 per hundredweight or $0.10 per gallon. As above, the farm price of milk is decreased in the fifth month by an equivalent $1.16 per hundredweight or $0.10 per gallon. Figure 3 shows that the estimated current month response to the farm price increase for the Compact period model ($0.117) was greater than the Pre-Compact current month response ($0.085). For the Compact model, the strong current month effect is followed by a small downward adjustment (the estimated one-month lag effect). In the final month of the adjustment, retail price increases once more. In the Pre-Compact model, the one-month lag effect causes retail price to rise again and the two-month lagged effects results in a slight decline in retail price. Retail price levels in month four represent the accumulated estimated effects for the single farm price increase of $0.10 per gallon. The Compact model estimated an increase of $0.120 per gallon in retail prices once the farm price increase effects were completed, a transmission rate of 120 percent. For the Pre-Compact model, retail prices rose by only $0.088, a transmission rate of 88 percent. Therefore, we do observe significantly different pricing conduct during the Compact period as opposed to the Pre-Compact period when farm prices increase.[6]

We next analyze the effects of a farm price decrease on Boston retail milk prices. In month five, farm price is decreased by an equivalent $0.10 per gallon. For the

[6] Recall the hypothesis of parameter equivalence across the two time periods was rejected (footnote 4). Figures 3 and 4 reflect these parameter differences across time periods.

Compact model, the estimated effect for the current month farm price decrease causes the retail price to drop quickly. This is followed by an upward adjustment to the retail price (the estimated one-month lag effect). The estimated two-month lag effect for the Compact model leads to a final decrease in the retail price. In the Pre-Compact model, the current month and lagged one-month effects are nearly identical with virtually no adjustment made in the final month of the simulation.

Interestingly, the two processes lead to the same result, after equivalent farm price increases and decreases, retail prices during the Pre-Compact and Compact periods would be higher by $0.068. Retail prices do not return to the same level as before the farm price increases and decreases. This is evidence of *long-run* price asymmetry.

Figure 4 shows the partial effect of equivalent farm price increases and decreases on Hartford retail prices. For the Pre-Compact model, the farm price increase of $0.10 per gallon in the second month led to a rapid increase in the current month ($0.050), followed by a slight decline after one month, and a final increase due to the two-month lag effect (month 4 on the graph). The sum of the farm price increase effects resulted in retail prices being $0.066 per gallon higher. Model estimates then show a relatively slow and steady decrease in retail prices when the farm price was decreased by an equivalent amount in the fifth month. For the Compact model, the response to the farm price increase was more dramatic, increasing by $0.081 in the current month. The one-month lag effect caused a further increase for a total of $0.104. Following a slight decline in the due to the two-month lag effect, Hartford retail prices settle at an increase of $0.100 after the lag process was completed, a transmission rate of 100 percent. Comparing this transmission rate to the Pre-Compact rate of 66 percent, we again see empirical evidence of different pricing conduct in the Compact period as compared to the Pre-Compact period.

As above, we analyze the effects of an equivalent decrease in the farm price on Hartford retail prices. Farm price is again decreased by $0.10 in month five. For the Compact model a rapid decline in retail price occurs followed by additional retail price decreases due to the one-month and two-month lag effects. For the Pre-Compact model, retail price decreases in response to the farm price decrease are smaller with virtually no change in the final month.

The aggregate responses of Hartford retail prices to equivalent farm price increases and decreases for the Compact model resulted in a smaller net increase when compared to the Pre-Compact results. After all estimated lagged effects were included, net increases in Hartford retail prices were $0.044 and $0.036 for the Pre-Compact and Compact models, respectively. While estimated long-run asymmetries in Hartford for both the Pre-Compact and Compact periods are smaller than those of Boston, there is again evidence that the farm-to-retail price margin would grow during both the Pre-Compact and the Compact periods, despite holding marketing costs constant. There is evidence of long-run farm-to-retail price asymmetry in Hartford.

Structural Change in Price Conduct: Pre-Compact versus Compact Results

The results above suggest a change in pricing behavior as a result of the Compact. Consider again the effects of the $0.10 increase in the farm price of milk and the subsequent transmission rates to retail milk prices. Lass, et al. (2001), estimated transmission rates of 63 percent (Boston) and 58 percent (Hartford) for the period 1982 through June 1996. Chidmi, Lopez and Cotterill (2004) found similar transmission rates using scanner data for the Boston area. For the current study, we find that the transmission rates for the Pre-Compact period (January 1990 through June 1997) were 88 percent and 66 percent for Boston and Hartford, respectively. The transmission rates increase in the Compact period to 120 percent in Boston and 100 percent in Hartford. Are these statistically important increases in transmission rates? Tests of equality of these estimated transmission rates were conducted as tests of the following linear restrictions for Compact period estimations:

$$\begin{aligned} &\textit{Boston}: \quad H_0: \pi_0^R + \pi_1^R + \pi_2^R = 3.783 \\ &\textit{Hartford}: H_0: \pi_0^R + \pi_1^R + \pi_2^R = 2.837 \end{aligned};$$

where the parameters are the rising farm price coefficients and the restriction values are sums from Pre-Compact estimation (see Tables 1 and 2). Calculated F-statistics were 4.52 and 4.65 for Boston and Hartford, respectively. For each test, the null hypothesis of equivalence is rejected at the five percent level of significance. Thus, we conclude that transmission rates for rising farm prices are statistically greater in the Compact period than in the Pre-Compact period.

Estimated transmission rates for falling farm prices from Lass, et al. (2001), were 63 percent (Boston) and 44 percent (Hartford). For the current study, transmission rates for falling farm prices in Boston were 20 percent for the Pre-Compact period and 52 percent for the Compact period. For Hartford, transmission rates were 22 percent and 64 percent for the Pre-Compact and Compact periods, respectively. Tests of restrictions similar to those described above lead to the conclusion that the falling farm transmission rates are also statistically different for the two periods for both Boston and Hartford at the five percent level of significance.

Why do transmission rates increase during the Compact period? Empirical evidence from this study lends support to the arguments of Cotterill and Franklin (2001) and Chidmi, Lopez and Cotterill (2004) that the Compact represents a “focal point” for tacit collusion and price increases (Schelling, 1960; Verboven, 1997). Major players in the New England milk market openly announced that the Compact would cause an $0.18 per gallon increase in the retail price of milk (Cotterill and Franklin, 2001). Thus, institution of the Compact provided a well-defined “focal point” through which firms were able to signal, very clearly, their intentions. This pricing behavior in response to increasing farm price is statistically different from the behavior estimated for the Pre-Compact period.

Hypothesis Tests of Asymmetry

Inferences from this study are that transmission rates for the Pre-Compact and Compact periods differ. But, do we also find evidence of asymmetric pricing behavior? Do we find that transmission rates for rising and falling farm prices differ within one period? Figures 3 and 4 suggest that given equivalent farm price increases and decreases, the retail price of milk will not return to its original level. The logical question is then: Are these observed asymmetric responses to farm price changes statistically important? There are two forms of asymmetric retail price adjustment for which we test. First, we test whether “short-run” asymmetries occur by comparing current and lagged effects for farm price increases and decreases. For example, if the current-month effect for a farm price increase is equivalent to the current-month effect of a farm price decrease, then we conclude there is no “short-run” asymmetry. The alternative is that retail prices respond differently (perhaps more rapidly) to farm price increases than to farm price decreases.

Second, we test whether there is no net change in retail price after equivalent farm price increases and decreases. Alternatively, equivalent increases and decreases in farm prices may lead to a net increase in retail milk prices, what is referred to as “long-run” asymmetry.

Hypotheses and test statistics are shown in Tables 3 (Boston) and 4 (Hartford). The hypotheses are presented as two-tail tests and were completed as t-tests. The first tests are of differences between estimated effects of rising farm prices and falling farm prices. Table 3 shows that for both the Boston Pre-Compact and Compact models, estimated current-month effects of rising farm prices were significantly greater than the estimated effects of falling farm prices suggesting a statistically greater speed of adjustment to rising farm prices than to falling farm prices.[7] The estimated rising and falling farm price effects for one-month and two-month lags were not statistically different. These results are consistent with the conclusions of Lass, et al. (2001) that retail milk prices show rapid responses to farm price changes, and that current month responses to rising farm prices are greater in magnitude than current month responses to falling farm prices. Estimated effects of rising farm prices on Hartford retail prices were also greater than estimated effects of falling farm prices (Table 4). Adherence to the two-tail hypothesis test at the five percent level of significance would lead us to conclude short-run asymmetry does not exist.[8] However, the calculated t-values are very close to the

[7] Tests were conducted as t-tests of the difference between the estimated parameters for rising farm prices and falling farm prices. A positive t-statistic indicates the rising farm price effect is greater in magnitude than the falling farm price effect, a negative t-statistics indicates the falling farm price effect is greater in magnitude.

[8] Note that the calculated t-values are very close to the critical t-values. A modest change in the level of significance, or a change to a one-tail test, would lead us to conclude that there is short-run asymmetry.

critical t-values for the current month effects. Lagged effects of rising farm prices are clearly not different from their counterpart fall farm price effects.

Tests of “long-run” price asymmetry are conducted by testing the difference between the sum of rising farm price coefficients and the sum of falling farm price coefficients. For the Compact model, these tests lead us to conclude that the observed differences shown in Figures 3 and 4 are statistically important for both Boston and Hartford. The sums of rising farm price coefficients are statistically greater than the sums of falling farm price coefficients at the one percent level of significance for the Compact models of both Boston and Hartford. For the Pre-Compact models, the calculated t-statistics for this “long-run” asymmetry test are close to the critical t-values. While the null hypothesis of no “long-run” asymmetry cannot be rejected as a two-tail test, it would be rejected in all cases if the test were conducted as a one-tail test where we impose a prior belief that the sum of the rising coefficients is greater than the sum of the falling coefficients.

Why does asymmetry exist in retail milk prices? And, given that asymmetry does exist, why might the rates of transmission increase from one period to the next as observed between the Pre-Compact and Compact periods in this study? While the mark-up price model offers no insights into observed asymmetries, there have been a variety of reasons suggested in the literature for price asymmetries. Our empirical results, which suggest retail milk prices rise rapidly, are in contrast to reasons for asymmetries suggested in the literature.

Price increases for perishable commodities may not be fully passed on to consumers to avoid the loss of product due to spoilage (Ward, 1982). But in this study, we find that farm price increases are rapidly passed on to consumers while the opposite is observed for price decreases. In addition, the transmission rates increase in the Compact period when compared to the Pre-Compact period. It is unlikely that the loss of product due to spoilage changes between the Pre-Compact and Compact periods. Thus, the product spoilage does not logically explain the asymmetry observed in this study.

Azzam (1999) has shown that the costs of re-pricing commodities can lead to sticky prices. Because of these costs, small to moderate price changes may not trigger retail price responses. Transmission rates found in the current study suggest farm price increases are rapidly passed on to consumers, thus retail milk prices are not sticky when the farm price increases. Long-run asymmetry suggests they are relatively sticky downwards when farm prices decrease. It is also not likely that the costs of re-pricing have changed between the Pre-Compact and Compact periods. Further, if re-pricing costs increased, we would hypothesize that the transmission rate in the Compact period would be lower than the rate in the Pre-Compact period. Thus, costs of re-pricing does not appear to be a logical explanation for differences in transmission rates and long-run asymmetry observed in this study. Similarly, other explanations for asymmetry such as changes in inventory management (Reagan and Weitzman, 1982) and search costs (Benson and Faminow, 1985) are not logical explanations for the results observed in this study.

Summary, Conclusions and Suggestions for Future Research

The approach of Kinnucan and Forker (1987), Lass, et al. (2001), and Frigon, et al. (1999) was followed to estimate retail milk price models for Boston, Massachusetts, and Hartford, Connecticut. In their study, Lass, et al. (2001) concluded that there was evidence of short-run price asymmetries in both Boston and Hartford, but that there was not sufficient evidence to conclude long-run asymmetry existed. However, their time series data extended from 1982 to June 1996, just prior to the institution of the Northeast Interstate Dairy Compact. In this study, time series data are extended through the period of the Compact (September 2001) allowing estimation of both Pre-Compact and Compact models.

The results of this study suggest that different structures exist for the two time periods. For the Pre-Compact period, time series data were found to be non-stationary requiring estimation in differences. Time series data for the Compact period were also non-stationary, but cointegrated, which allowed estimation in levels. These preliminary analyses of the time series properties of retail prices, farm prices and marketing costs suggest changing market structure. Separating the time series data at the date the Compact was instituted has economic support, but a more thorough investigation of the point at which parameters change would reveal more about changing market structure.

The results of this study suggest that pricing conduct has changed between the Pre-Compact period (January 1990 through June 1997) and the Compact period (July 1997 through September 2001). Transmission rates for farm price increases were statistically greater in the Compact period than in the Pre-Compact period. This result was found for both the Boston and Hartford markets. Transmission rates for farm price increases rose to from 88 percent to 120 percent in Boston, and from 66 percent to 100 percent in Hartford. These results support the arguments of that the Compact represented a focal point event for tacit collusion in retail pricing behavior (Cotterill and Franklin, 2001; Chidmi, Lopez and Cotterill, 2004).

Greater transmission rates were based on estimated parameters for current period and lagged farm price effects. These estimated coefficients were also used to determine whether short-run and long-run farm-to-retail price asymmetry exists in these two markets. Hypothesis tests lead to the conclusion that both short-run asymmetry (current month price effects) and long-run asymmetry exist in Boston and Hartford during the Compact period. Hypothesis tests of asymmetric behavior completed for the Pre-Compact periods were less compelling in both cities. The Pre-Compact results are consistent with prior evidence (i.e., Lass, et al., 2001; Frigon, et al., 1999). The Compact period results are a departure from prior evidence, which did not find compelling evidence of asymmetric retail milk price responses to farm milk price changes. The results of this study suggest a growing farm-to-retail price spread due to changes in farm prices, despite holding marketing costs constant.

The conclusion here is that retail milk prices do rise more rapidly than they fall. They also do not return to the same level following equivalent farm price increases and decreases thereby increasing the marketing margin. While the model used in this study provides a means to measure and test for these effects, it does not provide explanations for these observed phenomena. One direction for future research is the development of a theoretical model that will lead to testable hypotheses about the retail milk pricing conduct and to specification of a structural econometric model that provides a vehicle for testing these hypotheses. A convenient feature of the model used in this study is that only farm and retail price data are required while structural new empirical industrial organization models also require quantity data to estimate market power parameters. The lack of quantity data currently appears to be the limiting factor in our ability to identify causal effects using aggregate time series data.

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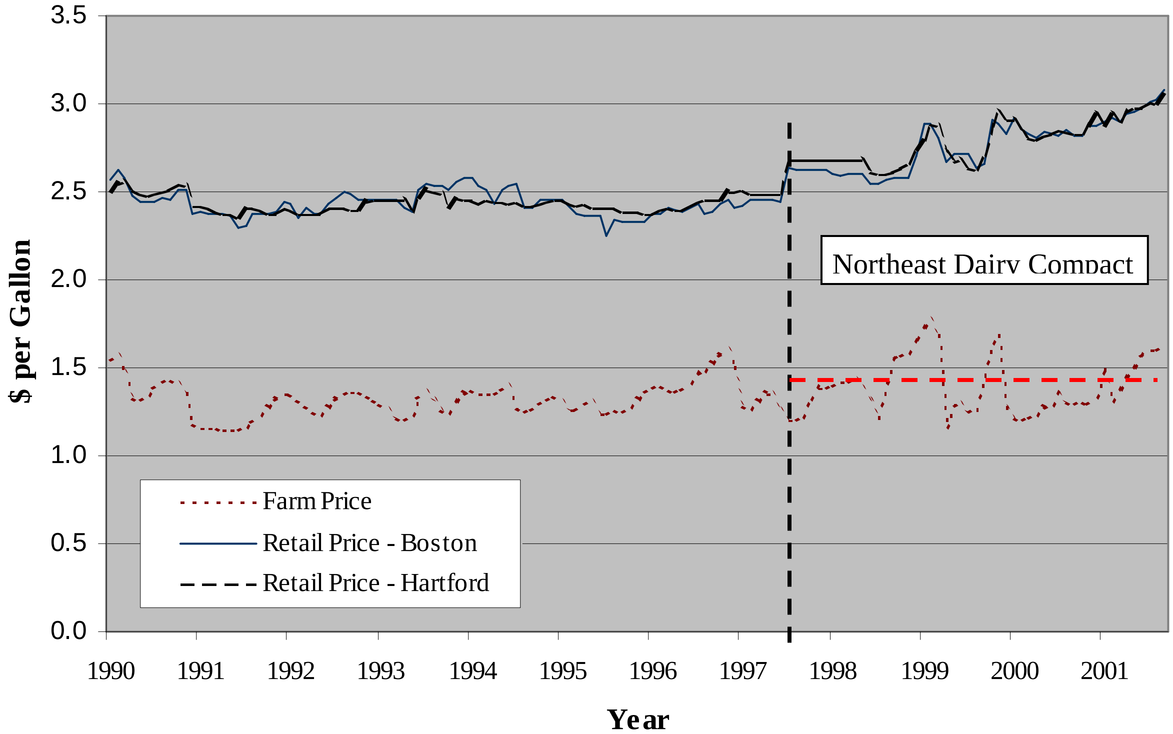

Figure 1 Farm and Retail Fluid Milk Prices for Boston and Hartford.

Source: Monthly data, January 1990 through September 2001. Farm price is the Class I price from the Federal Market Administrator's office. Retail prices are from the USDA, Agricultural Marketing Service.

Table 1: Estimated Boston Pre-Compact and Compact Retail Milk Price Models.

	Pre-Compact Period Jan. 1990 – June 1997		Compact Period July 1997 – Sept. 2001	
	Estimate	t_{calc}	*Estimate*	t_{calc}
Rising Farm Price Coefficients:				
Current Period	3.672	3.52*	5.042	7.58*
One Month Lag	0.330	0.28	-0.193	-0.28
Two Month Lag	-0.218	-0.22	0.314	0.46
Falling Farm Price Coefficients:				
Current Period	0.469	0.91	2.828	4.36*
One Month Lag	0.467	0.84	-1.309	-2.04*
Two Month Lag	-0.086	-0.16	0.711	1.24
Marketing Cost Index	0.052	0.38	0.269	2.57*
Trend	-0.652	-1.76*	-0.410	-4.90*
Aggregate Lagged Effects:				
Sum of Rising Coefficients	3.783	3.34*	5.162	7.96*
Sum of Falling Coefficients	0.850	1.23	2.230	3.66*
Difference	2.933	1.93*	2.933	5.08*
Sample Size	90		51	

* Statistically different from zero at the 5% level of significance.

Table 2: Estimated Hartford Pre-Compact and Compact Retail Milk Price Models.

	Pre-Compact Period Jan. 1990 – June 1997		Compact Period July 1997 – Sept. 2001	
	Estimate	t_{calc}	*Estimate*	t_{calc}
Rising Farm Price Coefficients:				
Current Period	2.165	3.17*	3.492	5.15*
One Month Lag	-0.308	-0.42	0.995	1.43
Two Month Lag	0.981	1.52	-0.187	-0.27
Falling Farm Price Coefficients:				
Current Period	0.586	1.74*	1.672	2.55*
One Month Lag	0.079	0.23	0.400	0.63
Two Month Lag	0.292	0.84	0.676	1.17
Marketing Cost Index	0.075	0.86	0.402	3.65*
Trend	-0.386	-1.42	-0.340	-3.80*
Aggregate Lagged Effects:				
Sum of Rising Coefficients	2.837	3.46*	4.300	6.34*
Sum of Falling Coefficients	0.957	1.91*	2.748	4.31*
Difference	1.880	1.69*	1.552	2.52*
Sample Size	90		51	

* Statistically different from zero at the 5% level of significance

Table 3: Hypothesis Tests of Asymmetric Retail Price Response for Boston Pre-Compact and Compact Models.

	Hypotheses	*Pre-Compact Period*	*Compact Period*
		t - Statistic	*t* - Statistic
Rising Farm Price Coefficients vs. Falling Farm Price Coefficients	$H_o : \pi_0^R = \pi_0^F \ ; \ H_a : \pi_0^R \neq \pi_0^F$	2.581*	2.445*
	$H_o : \pi_1^R = \pi_1^F \ ; \ H_a : \pi_1^R \neq \pi_1^F$	-0.102	1.117
	$H_o : \pi_2^R = \pi_2^F \ ; \ H_a : \pi_2^R \neq \pi_2^F$	-0.112	-0.419
Sum of Rising Coefficients vs. Sum of Falling Coefficients:	$H_o : \sum_{l=0}^{2} \pi_l^R = \sum_{l=0}^{2} \pi_l^F$ $H_a : \sum_{l=0}^{2} \pi_l^R > \sum_{l=0}^{2} \pi_l^F$	1.929	5.076*

* Statistically different from zero at the 5% level of significance. Critical t-values for two tail tests were 1.99 and 2.018 for the Pre-Compact and Compact models, respectively. Critical values for one-tail tests were 1.664 and 1.682 for the Pre-Compact and Compact periods, respectively..

Table 4: Hypothesis Tests of Asymmetric Retail Price Response for Hartford Pre-Compact and Compact Models.

	Hypotheses	*Pre-Compact Period*	*Compact Period*
		t - Statistic	*t* - Statistic
Rising Farm Price Coefficients vs. Falling Farm Price Coefficients	$H_o: \pi_0^R = \pi_0^F;\ H_a: \pi_0^R \neq \pi_0^F$	1.966	1.981
	$H_o: \pi_1^R = \pi_1^F;\ H_a: \pi_1^R \neq \pi_1^F$	-0.465	0.600
	$H_o: \pi_2^R = \pi_2^F;\ H_a: \pi_2^R \neq \pi_2^F$	0.895	-0.902
Sum of Rising Coefficients vs. Sum of Falling Coefficients:	$H_o: \sum_{l=0}^{2} \pi_l^R = \sum_{l=0}^{2} \pi_l^F$ $H_a: \sum_{l=0}^{2} \pi_l^R > \sum_{l=0}^{2} \pi_l^F$	1.689*	2.516*

* Statistically different from zero at the 5% level of significance. Critical t-values for two tail tests were 1.99 and 2.018 for the Pre-Compact and Compact models, respectively. Critical values for one-tail tests were 1.664 and 1.682 for the Pre-Compact and Compact periods, respectively.

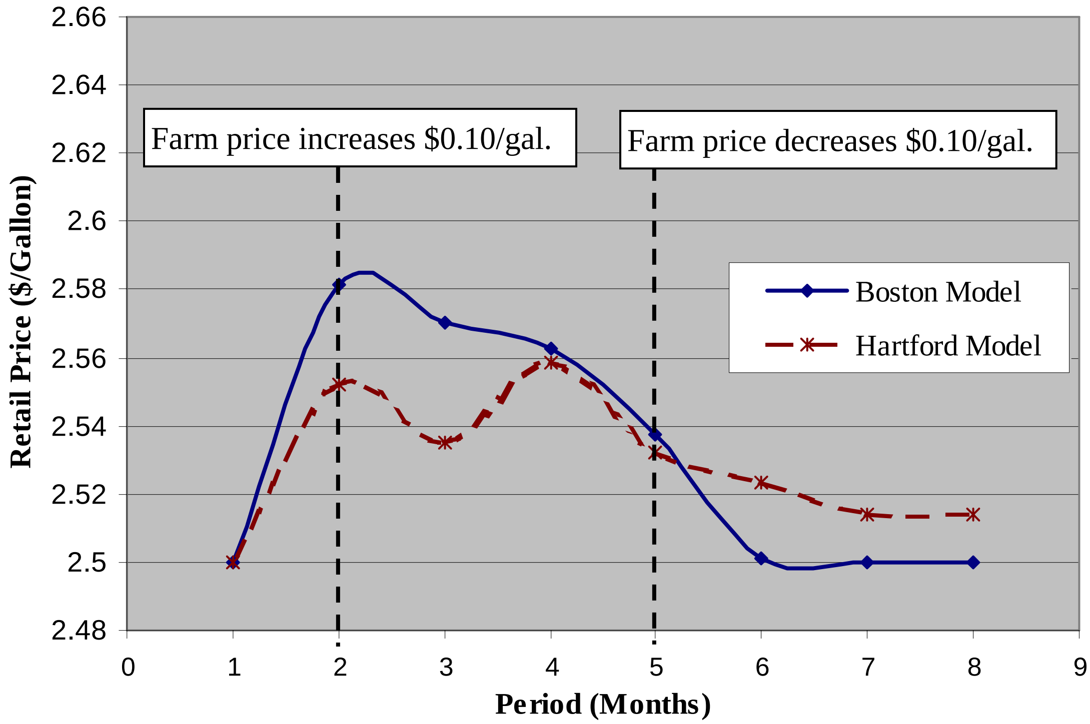

Figure 2 Lass, et al., estimated effects on retail milk price of an equivalent farm price increase and decrease, Boston and Hartford.

Source: Prepared by the author using estimated parameters of Lass, et al. Their study used monthly time-series data from January 1982 through June 1996.

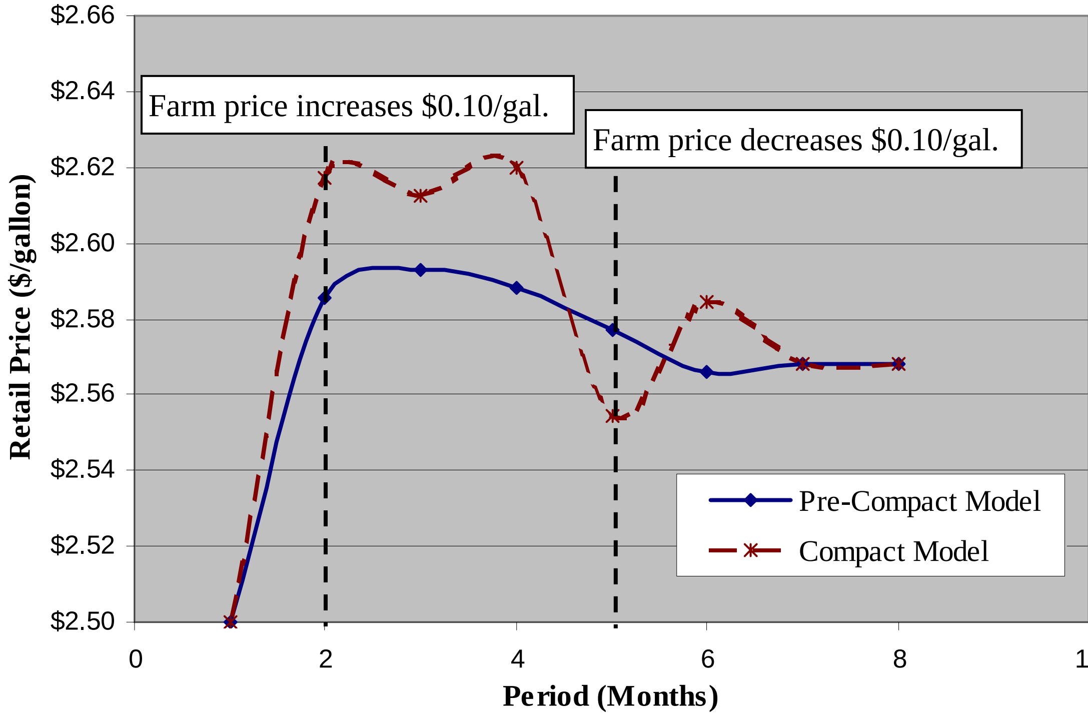

Figure 3 Current study estimated partial effects on retail milk price of an equivalent increase and decrease in the farm price of milk - Boston.

Data are monthly data for the Pre-Compact period, January 1990 through June 1997, and the Compact period, July 1997 through September 2001.

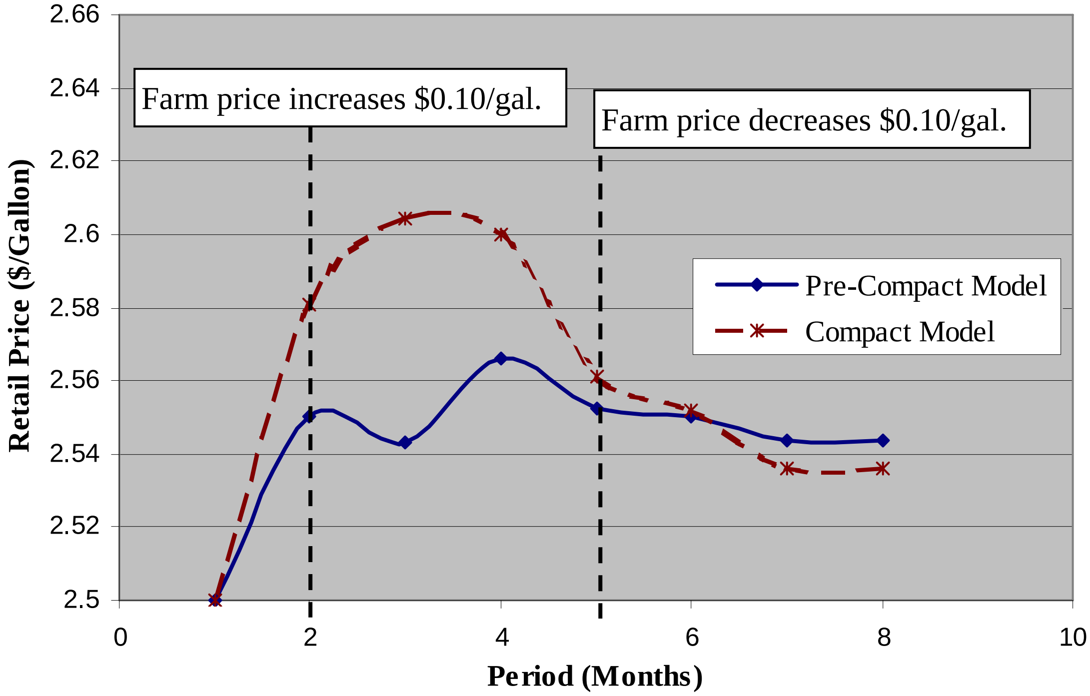

Figure 4 Current study estimated partial effects of an equivalent increase and decrease in the farm price of milk - Hartford.

Data are monthly data for the Pre-Compact period, January 1990 through June 1997, and the Compact period, July 1997 through September 2001.

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