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Market Power and Farm-Retail Price Transmission: The Case of U.S. Fluid Milk Markets

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In this paper we seek to understand the impact of market competitiveness on the degree of asymmetric price transmission and associated welfare implications. We estimate a kinked Almost Ideal Demand System for fluid milk products in 18 U.S. metropolitan areas. By conducting an asymmetric price transmission test, we find that cities with less competitive food retailing tend to exhibit asymmetric price transmission. The degree of price asymmetry and associated welfare loss are decreasing in the market competitiveness. Our welfare analysis suggests that the welfare loss due to asymmetric price transmission is large in terms of the percentage of milk expenditures. The potential is for substantially higher future welfare loss given the ongoing consolidation in food retailing industry.

Keywords: asymmetric price transmission, market power, milk

I. Introduction

Asymmetric price transmission, the phenomenon where downstream prices respond differently in speed or magnitude to an increase vs. decrease in upstream prices, has received considerable attention from economists and policy makers (Hassouneh et al. 2015). Economists are concerned about asymmetric price transmission because it is often incompatible with the prediction of standard economic theory (Peltzman 2000).[1] Public institutions are interested in price asymmetry due to the differential effects on producer vs. consumer surplus (Meyer and von Cramon-Taubadel 2004). With price asymmetry, consumers benefit less from farm milk price decreases when retail prices react slower compared to increased farm milk prices. This asymmetry results in welfare redistribution from consumers to food retailers.

Previous research has been undertaken to examine the asymmetry in the price transmission process for various products and markets. In a study of retail gasoline and crude oil prices, Borenstein, Cameron, and Gilbert (1997) found asymmetric price transmission between the spot prices of retail gasoline and crude oil prices. The asymmetry in price response was also observed in German pork market (von Cramon-Taubadel 1998). Analyzing a large number of diverse products, Peltzman (2000) found that output prices respond faster to input prices increases for a majority of commodities included in his analysis.

The study of price transmission for U.S. fluid milk products has become more important since the mid-1990s because of increasing volatility in milk prices shown in Figure 1 (Stewart and Blayney 2011). An indication of recent volatility can be obtained by examining All-Milk prices over the relatively short period, Nov. 2014 to Feb. 2015.[2] For Nov. 2014, the All-Milk price was

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[1] An example is the prediction in a perfectly competitive market without market friction.

[2] In the U.S., milk prices at the farm level are established monthly (Jesse and Cropp 2008). The average gross price received by farmers for milk is represented by a series commonly known as the All-Milk price.

$23.00 per hundred pounds (cwt) compared to $16.90/cwt in Feb. 2015, a 27% decrease over these three months. Given the degree of volatility that exists in the U.S. dairy industry, there is a potential for significant welfare redistribution if asymmetric price transmission in milk marketing indeed exists.

Previous literature has found evidence of asymmetric price transmission in U.S. fluid milk products when comparing farm vs. retail prices. Using monthly retail and farm milk price data encompassing the 1971-81 period, Kinnucan and Forker (1987) found that retail milk prices reacted more rapidly and fully to increased farm milk prices compared to farm price decreases. Capps and Sherwell (2007) demonstrated that price transmission elasticities associated with farm price increases are statistically larger than those associated with decreases for whole and reduced fat milk in seven U.S. cities. More recently, Awokuse and Wang (2009) and Stewart and Blayney (2011) continued to find asymmetric price transmission for fluid milk products.

The cause of asymmetric price transmission is often attributed to the lack of competition in the retail sector (Ward 1982; Damania and Yang 1998; Miller and Hayenga 2001;). This argument can be explained by the trigger price model proposed by Green and Porter (1984). In an oligopolistic market, retailers facing a decrease in costs will not change prices until they observe price reductions undertaken by other firms (Borenstein, Cameron, and Gilbert 1997). Alternatively, retailers will increase their prices immediately after a rise in costs to maintain margins. Previous research, however, tends not to analyze the impact of market competitiveness on the degree of price asymmetry and possible welfare consequences.[3]

In this paper, we utilize a kinked demand curve framework to understand the impact of market competitiveness on the degree of asymmetry in the price transmission process and possible welfare implication for consumers of U.S. fluid milk products. Our research strategy is first to use distributed lag and error correction models (ECM) to test for the existence of asymmetric price transmission. Secondly, we estimate a version of the classical Almost Ideal Demand System (AIDS), i.e., the Kinked Almost Ideal Demand System (K-AIDS) that allows for both convex and concave city specific fluid milk demand curves (Dossche, Heylen, and Van den Poel 2010). For this analysis we use monthly fluid milk sales data associated with 18 U.S. cities.[4] Third, we calculate market power parameters by extending the method proposed by McCorriston, Morgan, and Rayner (1998) to a multiproduct framework. We then examine the impact of market competitiveness on price transmission characteristics. Lastly, we evaluate the consumer welfare loss due to asymmetric price transmission in those markets exhibiting asymmetric price transmission.

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[3] Acharya, Kinnucan, and Caudill (2011) is one of the few attempts to analyze the relationship between market power and farm-retail price transmission. They use a finite-mixture model to estimate the middlemen market power of U.S. fresh strawberry market. In our study, instead of focusing the middlemen market power, we measure the market power of the retailers.

[4] For simplicity, we use the term city to indicate the metropolitan areas defined in our dataset. See Trade Dimensions (2009) for details on market definitions.

Our results suggest that fluid milk products exhibiting asymmetric price transmission are associated with less competitive markets. In addition, the degree of asymmetry and associated welfare loss are decreasing within the level of market competitiveness. We also find that the welfare loss due to asymmetric price transmission is large in terms of the percentage of milk expenditures. This welfare loss can be substantial in the future as food retailing is continuing to be increasingly concentrated (USDA/ERS 2017).

II. The Empirical Model for the Testing of Price Asymmetry

Asymmetric price transmission can be examined via the following distributed lag model that is comparable to the specification used by Capps and Sherwell (2007). The change in retail price of fluid milk, ΔR_t, can be represented via the following:

$$\Delta R_t = \beta_0 + \sum_{r=0}^{k} \beta_{1r} \Delta F_{t-r} + \sum_{r=0}^{k} \beta_{2r} D_{t-r}^{+} \Delta F_{t-r} + u_t, \tag{1}$$

where ΔF_{t-r} is the change in farm price at period $t-r$, D_{t-r}^{+} indicates a positive change in farm price in period $t-r$, and u_t is the error term with zero mean and heteroskedastic variance. k is the lag length. The use of this specification allows one to differentiate the effects of upward vs. downward changes in farm prices on retail milk prices.

To account for the possible cointegrated farm and retail prices that revert to their long-run relationship after deviation due to price shocks, we employ the error correction model (ECM) for cointegrated price series (Stewart and Blayney 2011). The long-run relationship of the price series can be described as follows:

$$R_t = \beta_0 + \beta_1 F_t + \varepsilon_t, \tag{2}$$

where ε_t is the error term with zero mean and heteroskedastic variance. Previous price asymmetry research has implemented alternative functional forms of error correction terms (ECTs). In this study, we divide ECTs into positive and negative components as suggested by Capps and Sherwell (2007):

$$\Delta R_t = \beta_0 + \sum_{r=0}^{k} \beta_{1r} \Delta F_{t-r} + \sum_{r=0}^{k} \beta_{2r} D_{t-r}^{+} \Delta F_{t-r} + \sum_{r=1}^{k} \gamma_r \Delta R_{t-r} + \lambda_1 ECT_t^{+} + \lambda_2 ECT_t^{-} + v_t, \tag{3}$$

where ECT_t^{+} and ECT_t^{-} are the error correction terms associated with the positive and negative deviations from the long-run relationship:

$$ECT_t^+ = \begin{cases} \varepsilon_{t-1} & if \quad \varepsilon_{t-1} \geq 0 \\ 0 & if \quad \varepsilon_{t-1} < 0 \end{cases} \quad \text{and} \quad ECT_t^- = \begin{cases} \varepsilon_{t-1} & if \quad \varepsilon_{t-1} < 0 \\ 0 & if \quad \varepsilon_{t-1} \geq 0 \end{cases}, \tag{4}$$

and v_t is the error term with zero mean and heteroskedastic variance.

We employ the Momentum-TAR (M-TAR) cointegration test suggested by Enders and Grangers (1998) to identify cointegrated price series. The M-TAR cointegration test is based on the equation describing the change in the ECTs:

$$\Delta\varepsilon_t = I_t \rho_1 \varepsilon_{t-1} + (1 - I_t)\rho_2 \varepsilon_{t-1} + \xi_t, \tag{5}$$

where

$$I_t = \begin{cases} 1 & if \quad \Delta\varepsilon_{t-1} \geq 0 \\ 0 & if \quad \Delta\varepsilon_{t-1} < 0 \end{cases}, \tag{6}$$

ρ_1 and ρ_2 are the unit root coefficients, and ξ_t is the error term with heteroskedastic variance. The price series are determined to be cointegrated when the null hypothesis that $\rho_1 = \rho_2 = 0$ is rejected.

The model specification we use for the test of asymmetry will be the distributed lag model if the farm-retail price series are not cointegrated vs. the ECM specification if cointegrated. The lag lengths, k, under both specifications are determined via the use of the AIC criterion.[5]

Under both model specifications, the hypothesis test of asymmetric price transmission is represented by:

$$H_0 : \sum_{r=0}^{\bar{k}} \beta_{2r} = 0, \qquad \bar{k} = 0, \ldots, k. \tag{7}$$

If there exists a $\bar{k}$ such that the null hypothesis is rejected, the market exhibits asymmetric price transmission.[6]

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[5] The range of lag length we examine is 0 to 6 months. We use this range because they are corresponded to the minimum and maximum lag lengths found in Capp and Sherwell (2007).

[6] This criterion is used by Romain, Doyon, and Frigon (2002) in their test of the short-run asymmetric price transmission.

III. Description of the K-AIDS Specification

In this analysis, we examine expenditures on four non-alcoholic beverages: whole milk, reduced fat milk, skim milk, and soda.[7] Our demand system is based on the K-AIDS specification originally specified by Dossche, Heylen, and Van de Poel (2010):

$$s_i = \alpha_i + \sum_{j=1}^{4} \gamma_{ij} \ln p_j + \beta_i \ln\left(\frac{X}{P}\right) + \sum_{j=1}^{4} \delta_{ij} \left[\ln\left(\frac{p_j}{P}\right)\right]^2, \tag{8}$$

where s_i is the expenditure share for good i, p_j is the price of good j, X is per capita expenditure on the 4-commodity food group, and P is the price index defined by Deaton and Muellbauer (1980) where

$$\ln P = \alpha_0 + \sum_{j=1}^{4} \alpha_j \ln p_j + \frac{1}{2} \sum_{j=1}^{4} \sum_{i=1}^{4} \gamma_{ij} \ln p_i \ln p_j. \tag{9}$$

The regression coefficients to be estimated are represented by α_0, α_i, β_i, γ_{ij}, and δ_{ij}. The term $\sum_{j=1}^{4} \delta_{ij} \left[\ln\left(p_j / P\right)\right]^2$ allows the demand function to exhibit concavity or convexity with respect to own price (Dossche, Heylen, and Van de Poel 2010). If $\delta_{ij} = 0$ for all i and j, the demand system reduces to the original AIDS specification. The homogeneity, adding-up, and symmetry assumptions are imposed by the following restrictions:

$$\sum_i \alpha_i = 1, \sum_i \beta_i = 0, \sum_i \gamma_{ij} = \sum_j \gamma_{ij} = 0, \gamma_{ij} = \gamma_{ji}, \sum_i \delta_{ij} = 0. \tag{10}$$

We use demographic scaling (Pollak and Wales 1981) to incorporate demographic variables that can affect non-alcoholic beverage demand. The scaling function takes the form:

$$\phi_i = \prod_l S_l^{\rho_{il}}, \tag{11}$$

where S_l is the l^{th} demographic variable and ρ_{il} is the parameter associated with the l^{th} demographic variable for i^{th} product. The value of ϕ_i can be interpreted as the number of product-specific "profile equivalents" (Gould, Cox, and Perali 1990).

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[7] Soda is included in the estimation system because we do not assume that milk products and soda are separable in consumer decision. This idea is supported by Zhen et al. (2013). Unfortunately, we do not have data on the sales of other non-alcoholic beverages in our IRI dataset.

The share equations given in equation (8) are reformulated with scaled prices, p_j^* and $\ln P^*$, to:

$$s_i = \alpha_i + \sum_{j=1}^{4} \gamma_{ij} \ln p_j^* + \beta_i \ln\left(\frac{X}{P^*}\right) + \sum_{j=1}^{4} \delta_{ij} \left[\ln\left(\frac{p_j^*}{P^*}\right)\right]^2, \tag{12}$$

where

$$p_j^* = p_j \phi_j \qquad \text{and} \qquad \ln P^* = \alpha_0 + \sum_{j=1}^{4} \alpha_j \ln p_j^* + \frac{1}{2} \sum_{j=1}^{4} \sum_{i=1}^{4} \gamma_{ij} \ln p_i^* \ln p_j^*. \tag{13}$$

To satisfy the homogeneity and adding-up conditions, we impose the following assumptions on scaling function parameters:

$$\sum_i \rho_{il} = 0 \qquad \forall l = 1, \ldots, L, \tag{14}$$

where L is the total number of demographic variables. Equation (14) implies that

$$\sum_i \ln \phi_i = 0. \tag{15}$$

IV. Measurement of the Impact of Market Competitiveness on Price Transmission

We measure the degree of market competitiveness by estimating the market power parameters proposed by McCorriston, Morgan, and Rayner (1998).[8] In their analysis, they identify market power parameter (θ) using the price-cost margin, $(p_i - c_i)/p_i$, obtained from the retailer's profit maximization problem:

$$\frac{p_i - c_i}{p_i} = -\frac{\theta_i}{\eta_i}, \tag{16}$$

where p_i is the retail price of product i, c_i is the retailer's marginal cost of product i, η_i is the own-price demand elasticity, and θ_i is the market power parameter. The intuition is that with $\theta_i = 1$, a market can be characterized as a monopoly. With $\theta_i = 0$, a market can be characterized as perfectly competitive.[9] With a negative own-price elasticity, the retail price increases as θ_i

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[8] Bresnahan (1982) and Lau (1982) also used this type of measurement for market power based on the markup.

[9] A higher θ_i indicates a less competitive market.

increases, ceteris paribus. The advantage of this method over the Lerner and Herfindahl-Hirschman indices (HHI) is that we can analyze the impact on retail price asymmetry under different levels of retail market competitiveness (i.e., alternative values of θ_i). Hovhannisyan and Gould (2012) used a similar markup model in their analysis of the market competitiveness of fluid milk retailers.[10]

As retailers often sell multiple products, we extend the above model to a multiproduct framework based on Tirole (1988) via the following:[11]

$$\frac{p_i - c_i}{p_i} = -\theta_i \left(\frac{1}{\eta_{ii}} + \sum_{j \neq i} \frac{\left(p_j - c_j\right) q_j \eta_{ji}}{p_i q_i \eta_{ii}} \right) = -\theta_i A_i, \tag{17}$$

where $A_i = 1/\eta_{ii} + \sum_{j \neq i} \left[\left(p_j - c_j \right) q_j \eta_{ji} \right] / \left(p_i q_i \eta_{ii} \right)$. For each observation, η_{ii} is the own-price elasticity of demand for good i, η_{ji} is the cross-price elasticity of demand for good j with respect to the price of good i, and q_i is the quantity demanded for the i^{th} good. Given equation (17), we can represent the market power parameter for each observation as

$$\theta_i = -\frac{p_i - c_i}{p_i} \cdot \frac{1}{A_i}. \tag{18}$$

To examine whether the asymmetric cities are less competitive than the non-asymmetric cities, we compute the average market power parameters of each product for two city types:

$$\overline{\theta}_i^A = \frac{1}{N} \sum_{n \in C} \theta_{in} \quad \text{and} \tag{19}$$

$$\overline{\theta}_i^{NA} = \frac{1}{N'} \sum_{n \in C'} \theta_{in}, \tag{20}$$

where $\overline{\theta}_i^A$ ($\overline{\theta}_i^{NA}$) is the average market power parameters across observations in asymmetric (non-asymmetric) cities and C (C') is the set for all observations in the asymmetric (non-asymmetric) cities with a total of N (N') observations. The test on the equality of market power parameters

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[10] Cakir and Balagtas (2012) also used a similar method to estimate the market power of U.S. dairy cooperatives in fluid milk market.

[11] For multi-product monopolistic firms, we have the same interpretation that $\theta_i = 1$ represents a monopoly and $\theta_i = 0$ represents a perfectly competitive market.

for product i between cities with asymmetric price transmission with their non-asymmetric counterpart can be represented as

$$H_0 : \overline{\theta}_i^{A} = \overline{\theta}_i^{NA}. \tag{21}$$

We use a Wald test to examine the equality of equation (21).

The above analysis is used to determine the relationship between market competitiveness and price asymmetry. It does not, however, imply a causal relationship. To understand how market competitiveness affects the degree of asymmetric price transmission, we examine the impact of the change in market power parameter on retail price changes under asymmetric and symmetric scenarios.

From equation (18), we can express the retail price of product i as

$$p_i = \frac{c_i}{1+\theta_i A_i}. \tag{22}$$

In the case of symmetric price transmission, the change of retail price of product i associated with a change of marginal cost from c_i to c_i', regardless of the direction, is

$$\Delta p_i^s = \frac{c_i' - c_i}{1+\theta_i A_i}. \tag{23}$$

In the case of asymmetric price transmission, however, the magnitude depends on the direction of the change in farm prices:

$$\begin{cases} \Delta p_i^a = \dfrac{c_i' - c_i}{1+\theta_i A_i} & if \quad c_i' \geq c \\ \Delta p_i^a = \dfrac{\left(\dfrac{\sum_{r=0}^{k^*} \beta_{1r}}{\sum_{r=0}^{k^*} \beta_{1r} + \sum_{r=0}^{k^*} \beta_{2r}} \right) \left(c_i' - c_i \right)}{1+\theta_i A_i} & if \quad c_i' < c_i \end{cases}, \tag{24}$$

where $\sum_{r=0}^{k^*} \beta_{1r}$ is the cumulative price response to a decrease in farm price for i^{th} product over k^* periods and $\sum_{r=0}^{k^*} \beta_{2r}$ is the difference in the cumulative price responses between an increase in farm price and a decrease over k^* periods.[12] k^* is the smallest lag length where asymmetric price transmission is detected (if any). $\sum_{r=0}^{k^*}\beta_{1r}\Big/\left(\sum_{r=0}^{k^*}\beta_{1r}+\sum_{r=0}^{k^*}\beta_{2r}\right)$ represents the ratio of cumulative price responses given a cost decrease to those given a cost increase. From equation (24), we can quantify the degree of asymmetry as the difference in retail price changes due to the same magnitude of cost increase vs. decrease:

$$\overline{\Delta p_i^a} = \Delta p_i^a \,|_{c_i' \geq c} - \left|\Delta p_i^a \,|_{c_i' < c}\right| = \frac{\left(1 - \dfrac{\sum_{r=0}^{k^*}\beta_{1r}}{\sum_{r=0}^{k^*}\beta_{1r} + \sum_{r=0}^{k^*}\beta_{2r}}\right)\left|\Delta c_i\right|}{1+\theta_i A_i}. \tag{25}$$

The impact of market competitiveness on the degree of asymmetric price transmission can be tested by

$$\frac{\partial \overline{\Delta p_i^a}}{\partial \theta} = 0. \tag{26}$$

A positive $\dfrac{\partial \overline{\Delta p_i^a}}{\partial \theta}$ indicates that the degree of asymmetry is decreasing in market competitiveness.

V. Description of the Data

The data used for this study come from three sources. We calculate the monthly weighted-average prices and expenditure shares of whole milk, reduced fat milk, skim milk, and soda from IRI retail price scanner data for 18 U.S. cities over the Jan. 2001- Dec. 2011 period (Bronnenberg, Kruger, and Mela 2008).[13] The demographic variables used to estimate the demand system are obtained from the IRI Infoscan data. Farm prices and marginal costs in this study are calculated based on the Class I price published by United States Department of Agriculture (USDA). There is a total of 2376 monthly city-level observations in our analysis.

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[12] $\sum_{r=0}^{k^*}\beta_{1r}+\sum_{r=0}^{k^*}\beta_{2r}$ represents the cumulative price responses to an increase in farm price over k^* periods. See equation (1) for the model specification.

[13] The original data was collected on a Universal Product Code (UPC) basis. Each milk product category is constructed by aggregating fluid milk products by UPC codes contained in our raw dataset. The whole milk commodity is defined as unflavored fluid milk with at least 3.25% butterfat content. For the reduced fat milk commodity, fat content is between 1-3.25%. The fat content for skim milk must be no more than 1%. As different store types may apply differing pricing strategy, we only include data for supermarkets.

As milk prices depend upon the component values, we adjust the farm prices given the weight of butterfat for whole, reduced fat, and skim milk. The calculation is based on the Class I price formula defined by the Federal Milk Marketing Orders (FMMOs) (Jesse and Cropp 2008):

$$\begin{aligned}&\text{Class I Price (\$/cwt)}\\&= 0.965\times\text{Class I Skim Milk Price (\$/cwt)}+0.035\times\text{Butterfat Price (\$/cwt)}.\end{aligned}\tag{27}$$

Class I price is based on milk with standard component values, i.e., 3.5% of butterfat, 3.1% of protein, and 5.9% of other solids.

To account for the difference of butterfat content across milk types, we calculate the farm prices of whole, reduced fat, and skim milk using the following formulas:

$$\begin{aligned}&\text{Farm Price for Whole Milk (\$/cwt)}\\&= 0.9675\times\text{Class I Skim Milk Price (\$/cwt)}+0.0325\times\text{Butterfat Price (\$/cwt)},\end{aligned}\tag{28}$$

$$\begin{aligned}&\text{Farm Price for Reduced Fat Milk (\$/cwt)}\\&= 0.98\times\text{Class I Skim Milk Price (\$/cwt)}+0.02\times\text{Butterfat Price (\$/cwt)},\end{aligned}\tag{29}$$

and

$$\begin{aligned}&\text{Farm Price for Skim Milk (\$/cwt)}\\&= 1\times\text{Class I Skim Milk Price (\$/cwt)}+0\times\text{Butterfat Price (\$/cwt)}.\end{aligned}\tag{30}$$

These formulas are based on the fat content of milk products in our data. Our sample shows that most of the milk products consumers purchase under the reduced fat and skim milk categories have 2% and 0% of butterfat, respectively. For whole milk, the fat content for the majority of products is not available in the form of percentage value. Therefore, we calculate the farm price for whole milk based on the standard of identity suggesting that whole milk have at least 3.25% of butterfat. The Class I skim milk price and butterfat price are both available from USDA.

As the marginal costs of milk products for retailers are unobservable, we estimate them by multiplying farm prices with the cooperative price premium based on announced cooperative Class I price obtained from USDA:

$$\text{Marginal Cost (\$/cwt)} = \text{Farm Price (\$/cwt)} \times \text{Cooperative Price Premium},\tag{31}$$

where

$$\text{Cooperative Price Premium} = \frac{\text{Annouced Cooperative Class I Price}}{\text{Class I Price}}. \tag{32}$$

Announced cooperative Class I price is the announced price including the additional charges for services performed by cooperatives to the processors (USDA/AMS 2010). Therefore, these announced prices are typically higher than the Class I prices.[14] We use Class I price in equation (32) because the announced cooperative Class I price is also based on standard component values.

Table 1 shows the average retail price, farm price, and expenditure shares of the whole, reduced fat, and skim milk for 9 selected cities.[15] The cities are selected to represent each of the 9 FMMO areas in our data.[16] The farm and retail milk prices are affected by city location due to county-specific Class I price differentials and alternative negotiated prices obtained across cooperatives and cities. Generally, the greater the distance from the Upper Midwest, the higher Class I differential will be. For example, New Orleans has a Class I differential of $3.80/cwt vs. a Chicago area Class I differential of $1.80/cwt. This generates a considerably higher Class I farm prices in the New Orleans area. The expenditure shares of milk products also differ across cities: the average expenditure share for whole milk is 6.9% for Chicago compared to 13.9% for Atlanta.

Figure 2 presents the retail and farm prices of reduced fat milk across time for Chicago. The retail and farm prices show similar patterns with the correlation coefficient of 0.81. Other cities in our analysis show similar price spreads.

VI. Estimation Procedures and Testing Results

In this section we present our empirical procedures and results. First, we will test the existence of price asymmetry given the parameter estimates from asymmetric price transmission models. Then we will estimate the K-AIDS and obtain the estimated elasticities. The last step is to test the equality of market competitiveness between asymmetric and non-asymmetric cities and examine the impact of market competitiveness on the degree of price asymmetry.

VI.A Asymmetric Price Transmission

The first step of our analysis is to identify the cointegration of farm-retail milk price series and to determine city-specific lag length for each product. About half of our farm and retail milk price

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[14] In our data, the cooperative price premium for each monthly observation is greater than 1.

[15] See Appendix Table A1 and Table A2 for data of all 18 cities where soda data are also included.

[16] Our sample does not include cities in Appalachian Marketing Ordering area.

series are found to be cointegrated. The lag length for each product in each city range from 0 to 4, with most having a 1 period lag.[17]

Based on the determined model specification given in equation (1) or (3), we estimate the model for each product and city using OLS. Table 2 reports the sum of coefficients on the change in farm prices for the selected 9 cities.[18] Given the parameter estimates, we conduct a Wald test to examine the asymmetric price transmission for each milk product in each city given in equation (7). Table 3 presents the resulting chi-squared statistics and p-values. Our results suggest that skim milk in about two-third of the cities exhibits price asymmetry. For whole milk and reduced fat milk, the numbers of asymmetric cities are about one-third.

Does the asymmetric price transmission persist in the long run?[19] From Table 2, $\sum_{r=0}^{k}\beta_{2r}$ for all milk products in most of the cities are not significant different from 0. This suggests that the asymmetry in price responses tend to disappear in the long run even though they are commonly found across cities.

VI.B City-Specific Demand Curves

We estimate the K-AIDS using seemingly unrelated regression (SUR) procedure. As the estimation of α_0 is often difficult, previous literature suggests that it should be set slightly lower than the minimum of $\ln(X)$, the log of per capita expenditure (Deaton and Muellbauer 1980; Banks, Blundell, and Lewbel 1997; Poi 2012). We follow this practice and set α_0 to -1.[20] The equation for soda is dropped from the estimation.[21]

Previous studies have found significant ethnicity and income impacts on the structure of fluid milk demand (Davis et al. 2012). Therefore, we include the following demographic variables: the proportion of population identified as Black population; the proportion identified as Hispanic population; the proportion identified as Asian population; the proportion of households with income over $75,000; the proportion of households with income below $25,000; and a set of city-specific binary indicators identifying each city.[22]

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[17] See Appendix Table A3 for determined model specifications.

[18] See Appendix Table A4 for full results.

[19] Long-run asymmetry refers to the type of asymmetric price transmission that persists after a complete adjustment period (Romain, Doyon, and Frigon 2002).

[20] The minimum $\ln(X)$ in our data is 0.27. We choose the α_0 that yields the minimum sum of squared errors using a grid search method between -2 and 0 with 0.1 increment.

[21] Because of the adding-up restriction given in equations (10) and (14), only three equations in the four-equation system are independent.

[22] Following Suit (1984), we include the full set of city indicators with the constraint that the parameters sum to zero.

Estimating the demand system given in equation (12), we find that all price coefficients are statistically significant.[23] For the coefficients on squared prices, only that for skim milk on reduced fat milk expenditure share is insignificant. Most of the coefficients associated with the demographic variables are also highly significant. The R-sq for each equation is higher than 0.84. This indicates that our model has high explanatory power. The aggregated demand curves for Boston, Chicago, Dallas, and Seattle are shown in Figure 3. Our estimates of compensated and expenditure elasticities for all products suggest that all own-price elasticities are significantly negative.[24] We also found that all cross-price elasticities are positive, indicating the substitutable nature across these four products.

VI.C The Relationship Between Market Competitiveness and Price Asymmetry

Given equation (18), the market power parameters can be obtained from the estimated elasticities. To test whether products exhibiting asymmetric price transmission are associated with less competitive markets, we conduct the Wald test for the equality of market power parameters between asymmetric and non-asymmetric cities for whole milk, reduced fat milk, and skim given in equation (21). The results are shown in Table 4. For all milk products, we reject the null hypothesis that the average market power parameters for the asymmetric and non-asymmetric cities are the same under 0.05 significance level. Since the market power parameters for the asymmetric cities are higher, our results indicate that less competitive markets tend to exhibit asymmetric price transmission.

The difference in degree of market competitiveness between asymmetric and non-asymmetric cities can be better understood in terms of the difference in price-cost margins. Using equation (22), we calculate the estimated retail prices of product i for two groups given the market power parameters fixed at its group mean and all other variables fixed at the mean of all observations. The results are presented in Table 5. This suggests that the asymmetric group is associated with 7~17% higher estimated retail prices of milk products.

The impact of market competitiveness on the degree of asymmetry can be identified by examining how market power parameters impact the resulting price difference between the same magnitude of cost increase and decrease. If $\partial\overline{\Delta p_i^a}\big/\partial\theta > 0$ for all observations in the asymmetric markets, then the degree of asymmetry is decreasing in market competitiveness. From equation (25), $\partial\overline{\Delta p_i^a}\big/\partial\theta > 0$ if and only if the multiplier $A_i < 0$ given $\left\{1-\left[\sum_{r=0}^{k^*}\beta_{1r}\Big/\left(\sum_{r=0}^{k^*}\beta_{1r}+\sum_{r=0}^{k^*}\beta_{2r}\right)\right]\right\}|\Delta c_i| > 0.$ Therefore, we compute the multiplier A_i for each asymmetric city to examine the impact. Our results in Table 6 indicate that lower market competitiveness produces higher the degree of asymmetry.

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[23] See Appendix Table A5 for the parameter estimates.

[24] See Appendix Table A6 for the estimates of the elasticities.

VII. Welfare Analysis

We estimate the welfare loss of asymmetric price transmission by calculating the welfare change due to the decrease in farm price under price asymmetry vs. symmetric scenario. That is, we measure the additional welfare consumers could have gotten due to a decrease in farm price if asymmetric price transmission did not exist.

The difference in price change between asymmetric and symmetric price transmission when cost goes down from c_i to c_i' can be expressed as

$$\Delta p_i^a - \Delta p_i^s = \frac{\left(1 - \frac{\sum_{r=0}^{k^*} \beta_{1r}}{\sum_{r=0}^{k^*} \beta_{1r} + \sum_{r=0}^{k^*} \beta_{2r}}\right)(c_i - c_i')}{1 + \theta_i A_i}. \tag{33}$$

As our estimation results show that $\sum_{r=0}^{k^*} \beta_{1r} \Big/ \left(\sum_{r=0}^{k^*} \beta_{1r} + \sum_{r=0}^{k^*} \beta_{2r}\right) < 1$ and $1 + \theta_i A_i > 0$ for all i, we know that $\Delta p_i^a - \Delta p_i^s > 0$. This suggests that given a cost decrease, the price reduction for a product under symmetric price transmission is greater than its counterpart under asymmetric price transmission.[25] The lower price reduction from asymmetric price transmission leads to consumer welfare loss.

We measure the welfare loss via the change in consumer surplus. The consumer surplus associated with a change in price from p to p' can be represented as (Varian 1992):

$$CS_i = \int_p^{p'} q_i(t)dt, \tag{34}$$

where CS_i is the consumer's surplus of product i and q_i is the quantity demanded that is the function of its price. The welfare loss due to asymmetric transmission in each city for product i can be expressed as

$$WL_i = CS_i^{p^S:p^A} = \int_{p^S}^{p^A} q_i(t)dt, \tag{35}$$

where p^S and p^A are the retail prices associated with a marginal cost decrease under symmetric and asymmetric price transmission, respectively.

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[25] Note that both Δp_i^a and Δp_i^s are negative given a decrease in cost.

We can also measure the welfare loss as a percentage of monthly expenditure on a specific milk product ($WL_i^{\%}$):

$$WL_i^{\%} = \frac{CS_i^{p^S:p^A}}{EXP_i}, \tag{36}$$

where EXP_i is the monthly expenditure for product i.

Table 7 reports the welfare loss from a \$0.30 decrease in marginal cost due to asymmetric price transmission as a percentage of expenditure for each milk product.[26] The average welfare loss ranges from about 17% to 28%. For skim milk in Phoenix, the percentage is as high as 55%. This indicates that the welfare losses are large in terms of the percentage of consumer expenditure on milk products. This result has important implication on future consumer welfare. Previously we have shown that the degree of asymmetry and therefore the welfare loss increase when the market becomes less competitive.[27] As the food retailing industry has become increasingly concentrated, there might be substantial welfare loss in the future if asymmetric price transmission persists.

VIII. Summary and Conclusion

Market power is often considered the major cause of asymmetric retail price transmission. Few studies, however, analyze how market competitiveness impacts price asymmetry. In this paper, we construct a kinked demand curve framework to understand the impact of market competitiveness on the degree of asymmetry and possible welfare implications.

With the analysis of the fluid milk products across 18 U.S. cities, we demonstrated that less competition produces more asymmetry and therefore consumer welfare impacts. This is consistent with our finding that asymmetric markets are, on average, less competitive. That is, retailers were able to set significantly higher prices over the study period. We also find that the welfare loss due to asymmetric price transmission is large when measured as the percentage of milk expenditure. With a \$0.30 decrease in marginal cost, consumers could have gotten higher surplus ranging from about 17% of whole milk expenditure to 28% of skim milk expenditure on average if the asymmetry does not exist. As the loss of welfare is negatively related with market competitiveness, the ongoing trend of consolidation in the food retailing might cause substantial welfare loss in the future.

We encourage future research to explore other factors that might also cause asymmetric price transmission. One possible candidate is the adjustment cost. Peltzman (2000) argued that in the

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[26] We pick \$0.30 because it is approximately the standard deviation of the marginal cost of each milk product.

[27] As $\overline{\Delta p_i^a} = \Delta p_i^a - \Delta p_i^s$, we have $\partial \overline{\Delta p_i^a} / \partial\theta = \partial(\Delta p_i^a - \Delta p_i^s)/\partial\theta$.

short run, it is harder for firms to increase production when the cost of inputs goes down than to decrease production when the cost increases because the former requires the recruitment of new inputs. In addition, policy intervention might cause asymmetric price transmission even if the market is relatively competitive (Gardner 1975; Kinnucan and Forker 1987). Identifying alternative causes of asymmetry will provide important insights into the magnitude of possible welfare impacts of asymmetric price transmission.

Table 1: Average Retail Prices, Farm Prices, and Expenditure Shares of Whole, Reduced Fat, and Skim Milk for 9 Selected Cities

	Whole Milk			Reduced Fat Milk			Skim Milk			
	Retail Price ($/gal)	Farm Price ($/gal)	Expenditure Share	Retail Price ($/gal)	Farm Price ($/gal)	Expenditure Share	Retail Price ($/gal)	Farm Price ($/gal)	Expenditure Share	Federal Marketing Order
Atlanta	3.64	1.50	0.139	3.68	1.34	0.168	3.76	1.09	0.167	Southeast
	(0.47)	(0.30)	(0.025)	(0.44)	(0.28)	(0.014)	(0.46)	(0.25)	(0.023)	
Chicago	3.42	1.35	0.069	3.37	1.19	0.153	3.57	0.93	0.154	Upper Midwest
	(0.30)	(0.28)	(0.007)	(0.26)	(0.26)	(0.015)	(0.31)	(0.24)	(0.015)	
Cleveland	3.55	1.37	0.078	3.22	1.21	0.187	3.35	0.95	0.179	Mideast
	(0.45)	(0.28)	(0.009)	(0.45)	(0.26)	(0.016)	(0.47)	(0.24)	(0.025)	
Dallas	3.10	1.46	0.179	3.15	1.30	0.139	3.33	1.04	0.083	Southwest
	(0.56)	(0.28)	(0.028)	(0.54)	(0.26)	(0.015)	(0.51)	(0.24)	(0.008)	
New Orleans	4.21	1.53	0.160	4.38	1.37	0.125	4.38	1.11	0.119	Southeast
	(0.61)	(0.29)	(0.017)	(0.67)	(0.27)	(0.018)	(0.64)	(0.24)	(0.012)	
Oklahoma City	3.58	1.42	0.132	3.51	1.26	0.133	3.56	1.01	0.081	Central
	(0.48)	(0.28)	(0.020)	(0.46)	(0.26)	(0.024)	(0.54)	(0.24)	(0.010)	
Phoenix	2.69	1.41	0.122	2.70	1.26	0.167	2.88	1.00	0.140	Arizona
	(0.29)	(0.29)	(0.015)	(0.25)	(0.27)	(0.014)	(0.25)	(0.24)	(0.012)	
Seattle	3.82	1.37	0.101	3.41	1.21	0.205	3.57	0.95	0.183	Pacific Northwest
	(0.24)	(0.29)	(0.008)	(0.22)	(0.26)	(0.013)	(0.21)	(0.24)	(0.013)	
Washington DC	3.92	1.45	0.139	3.96	1.29	0.143	4.14	1.03	0.184	Northeast
	(0.51)	(0.28)	(0.010)	(0.56)	(0.26)	(0.012)	(0.57)	(0.24)	(0.018)	
Total U.S.	3.56	1.41	0.110	3.47	1.25	0.148	3.53	1.00	0.175	N/A
	(0.59)	(0.29)	(0.043)	(0.61)	(0.27)	(0.030)	(0.65)	(0.25)	(0.055)	

Note: Standard deviations are reported in the parentheses. Total U.S. represents the average statistics of 18 cities in our data.

Table 2: Summary of the Parameter Estimates for Price Transmission Model for 9 Selected Cities

	Sum of Coefficients on Changes in Farm Prices					
	Whole Milk		Reduced Fat Milk		Skim Milk	
	$\sum_{r=0}^{k}\beta_{1r}$	$\sum_{r=0}^{k}\beta_{2r}$	$\sum_{r=0}^{k}\beta_{1r}$	$\sum_{r=0}^{k}\beta_{2r}$	$\sum_{r=0}^{k}\beta_{1r}$	$\sum_{r=0}^{k}\beta_{2r}$
Atlanta	0.852**	0.114	1.003**	-0.019	0.837**	0.154
	(0.218)	(0.261)	(0.275)	(0.275)	(0.218)	(0.211)
Chicago	0.560*	0.341	0.258	0.542	0.247	0.603
	(0.201)	(0.332)	(0.164)	(0.283)	(0.135)	(0.255)
Cleveland	0.242	0.692	0.426	1.001*	0.280	0.490
	(0.263)	(0.382)	(0.319)	(0.407)	(0.224)	(0.278)
Dallas	0.540**	0.320	0.594**	0.267	0.368*	0.325
	(0.189)	(0.339)	(0.178)	(0.338)	(0.157)	(0.281)
New Orleans	0.831**	0.124	0.839**	0.106	0.437*	0.599**
	(0.199)	(0.236)	(0.187)	(0.234)	(0.173)	(0.189)
Oklahoma City	0.515*	0.350	0.651**	0.269	0.453**	0.419
	(0.233)	(0.444)	(0.229)	(0.464)	(0.144)	(0.286)
Phoenix	0.286	0.789*	1.186**	0.096	1.300**	0.159
	(0.355)	(0.365)	(0.392)	(0.324)	(0.430)	(0.298)
Seattle	0.380	0.773*	-0.034	0.700**	0.086	0.508**
	(0.263)	(0.385)	(0.132)	(0.222)	(0.094)	(0.178)
Washington DC	0.701**	0.010	0.749**	0.026	0.579**	0.062
	(0.127)	(0.155)	(0.131)	(0.134)	(0.131)	(0.159)

Note: Robust standard errors are reported in the parentheses. $\sum_{r=0}^{k}\beta_{1r}$ is the cumulative price response to a decrease in farm price for product i over k periods and $\sum_{r=0}^{k}\beta_{2r}$ is the difference in the cumulative price responses between an increase in farm price and a decrease over k periods.

**significant at 0.01 significance level

*significant at 0.05 significance level

Table 3: Price Asymmetry Test Chi-Squared Statistic Values

City	Whole Milk	Reduced Fat Milk	Skim Milk	City	Whole Milk	Reduced Fat Milk	Skim Milk
Atlanta	3.41	2.79	5.02*	Minneapolis	0.70	1.72	4.16*
	(0.065)	(0.095)	(0.025)		(0.403)	(0.190)	(0.041)
Boston	0.42	0.84	0.28	New Orleans	5.09*	3.73	10.08**
	(0.517)	(0.359)	(0.597)		(0.024)	(0.053)	(0.001)
Chicago	3.35	3.67	5.57*	Oklahoma City	2.09	0.84	2.15
	(0.067)	(0.055)	(0.018)		(0.148)	(0.359)	(0.143)
Cleveland	5.28*	6.04*	8.52**	Omaha	0.21	5.03*	1.62
	(0.023)	(0.014)	(0.004)		(0.647)	(0.025)	(0.203)
Dallas	1.61	1.76	1.34	Philadelphia	11.95**	3.03	6.22*
	(0.204)	(0.185)	(0.247)		(0.001)	(0.082)	(0.013)
Detroit	2.09	1.16	2.30	Phoenix	12.71**	9.80**	13.44**
	(0.148)	(0.281)	(0.129)		(0.000)	(0.002)	(0.000)
Hartford	2.37	3.67	4.16*	Saint Louis	10.57**	10.28**	15.59**
	(0.124)	(0.058)	(0.041)		(0.001)	(0.001)	(0.000)
Kansas City	2.02	0.93	1.86	Seattle	9.29**	9.93**	8.15**
	(0.155)	(0.335)	(0.173)		(0.002)	(0.002)	(0.004)
Milwaukee	1.03	1.32	2.70	Washington DC	8.66**	14.09**	9.48**
	(0.310)	(0.251)	(0.100)		(0.003)	(0.000)	(0.002)
Number of Asymmetric Cities	7	6	11				

Note: p-values are shown in the parentheses. Testing results with the highest chi-squared statistics are shown.
**significant at 0.01 significance level
*significant at 0.05 significance level

Table 4: Result of Test on the Equality of Market Power Parameter between Asymmetric and Non-Asymmetric Cities

	Whole Milk	Reduced Fat Milk	Skim Milk
Mean market power parameter for APT cities	0.5208**	0.4131**	0.6027**
	(0.0132)	(0.0122)	(0.0087)
Mean market power parameter for non-APT cities	0.4907**	0.3897**	0.5582**
	(0.0147)	(0.0144)	(0.0094)
Difference	0.0301**	0.0234**	0.0445**
	(0.0017)	(0.0023)	(0.0009)
Reject H_0 under 0.05 significance level	Yes	Yes	Yes

Note: Standard errors are shown in the parentheses. We use the Delta method to compute the standard errors.

**significant at 0.01 significance level

Table 5: Estimated Retailed Prices for Asymmetric and Non-Asymmetric Cities

	Whole Milk	Reduced Fat Milk	Skim Milk
Estimated Retail Price for	3.62**	3.72**	3.73**
APT cities	(0.12)	(0.22)	(0.14)
Estimated Retail Price for	3.37**	3.40**	3.19**
non-APT cities	(0.10)	(0.17)	(0.09)
Difference	0.25**	0.32**	0.54**
	(0.02)	(0.05)	(0.04)
Percentage Difference	7.35%	9.25%	17.13%

Note: Standard errors are shown in the parenthesis. All values are evaluated at the mean value of the data.

**significant at 0.01 significance level

Table 6: Maximum Multiplier A_i for All Products in the Asymmetric Cities

City	Whole Milk	Reduced Fat Milk	Skim Milk	City	Whole Milk	Reduced Fat Milk	Skim Milk
Atlanta			-1.11**	Minneapolis			-1.16**
			(0.01)				(0.01)
Boston				New Orleans	-1.04**		-1.25**
					(0.01)		(0.01)
Chicago			-1.13**	Oklahoma City			
			(0.02)				
Cleveland	-1.07**	-1.31**	-1.12**	Omaha		-1.46**	
	(0.03)	(0.03)	(0.01)			(0.05)	
Dallas				Philadelphia	-1.04**		-1.11**
					(0.01)		(0.01)
Detroit				Phoenix	-1.03**	-1.32**	-1.12**
					(0.02)	(0.05)	(0.02)
Hartford			-1.09**	Saint Louis	-1.11**	-1.35**	-1.15**
			(0.01)		(0.04)	(0.03)	(0.02)
Kansas City				Seattle	-1.07**	-1.31**	-1.29**
					(0.03)	(0.03)	(0.02)
Milwaukee				Washington DC	-1.06**	-1.41**	-1.11**
					(0.02)	(0.04)	(0.01)

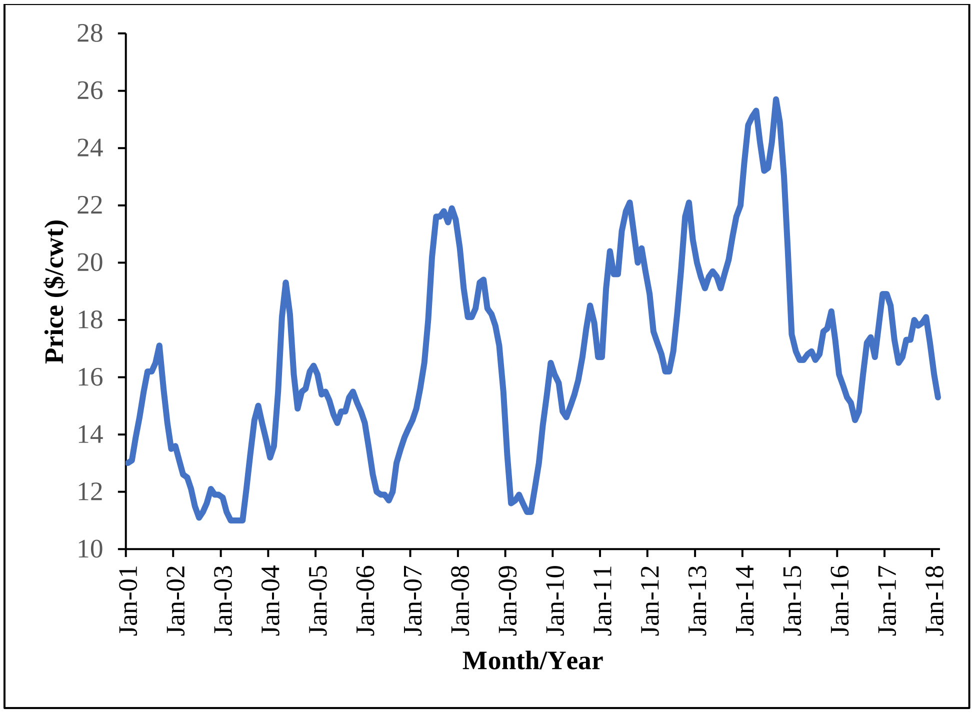
Note: The multiplier $A_i = 1/\eta_{ii} + \sum_{j \neq i}\left[\left(p_j - c_j\right)q_j\eta_{ji}\right]/\left(p_i q_i \eta_{ii}\right)$. Standard errors are shown in the parentheses. Products that do not exhibit asymmetric price transmission are not analyzed.
**significant at 0.01 significance level

Table 7: Welfare Loss from the Asymmetric Price Transmission as the Percentage of Expenditure on Milk Products

City	Whole Milk	Reduced Fat Milk	Skim Milk	City	Whole Milk	Reduced Fat Milk	Skim Milk
Atlanta			15.5%	Minneapolis			23.0%
Boston				New Orleans	12.7%		27.7%
Chicago			33.3%	Oklahoma City			
Cleveland	15.3%	17.1%	26.3%	Omaha		13.6%	
Dallas				Philadelphia	9.4%		12.4%
Detroit				Phoenix	22.9%	29.5%	54.9%
Hartford			19.8%	Saint Louis	15.2%	17.9%	24.5%
Kansas City				Seattle	26.0%	29.0%	38.0%
Milwaukee				Washington DC	14.8%	20.6%	25.4%
Average	16.6%	21.3%	28.2%				

Note: Products that do not exhibit asymmetric price transmission are not analyzed.

Figure 1: U.S. Monthly All-Milk Price, Jan. 2001 to Feb. 2018



Note: All-Milk price is the average gross prices received by farmers for milk sold at average fat test.

Figure 2: Retail-Farm Price Series of Reduced Fat Milk for Chicago from Jan. 2001 to Dec. 2011

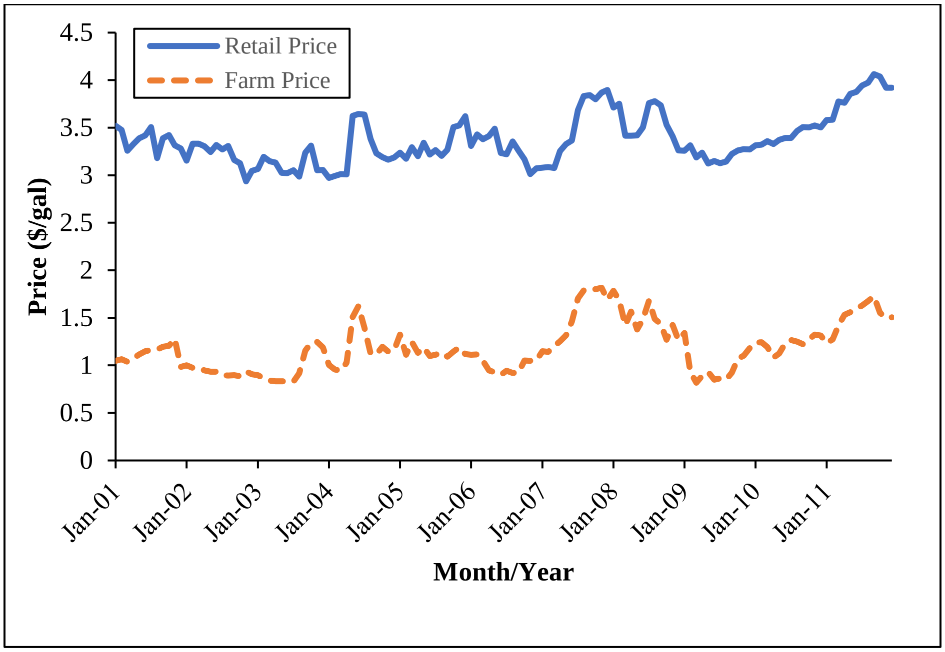
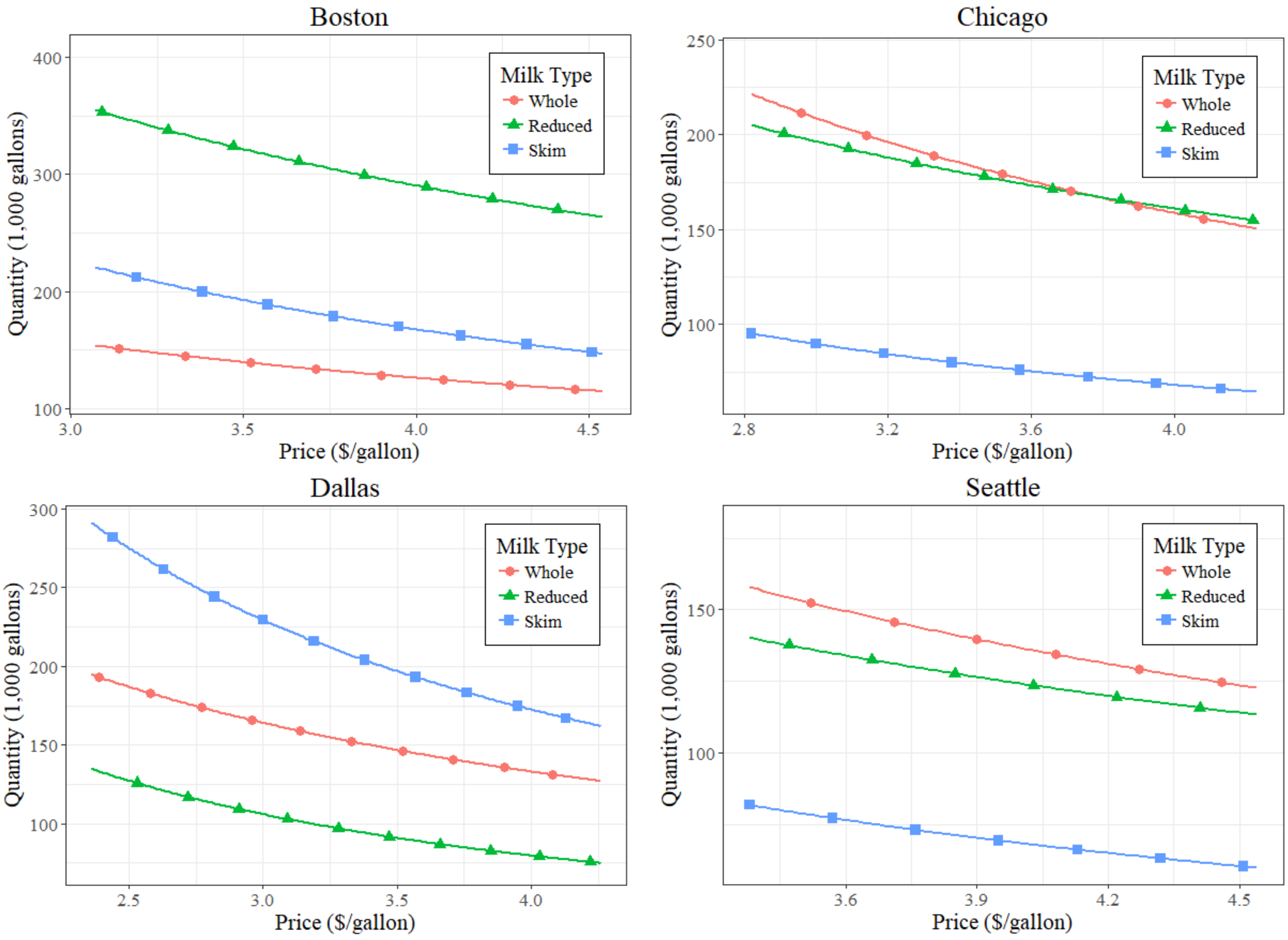


Figure 3: Estimated Aggregated Monthly Demand of Milk Products in 4 Selected Cities


Boston

Chicago

Dallas

Seattle

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Appendix

Table A1: Average Retail Prices, Farm Prices, and Expenditure Shares of Whole and Reduced Fat Milk for All Cities

	Whole Milk			Reduced Fat Milk			
	Retail Price ($/gal)	Farm Price ($/gal)	Expenditure Share	Retail Price ($/gal)	Farm Price ($/gal)	Expenditure Share	Marketing Order
Atlanta	3.64	1.50	0.139	3.68	1.34	0.168	Southeast
	(0.47)	(0.30)	(0.025)	(0.44)	(0.28)	(0.014)	
Boston	3.56	1.47	0.148	3.64	1.31	0.113	Northeast
	(0.36)	(0.28)	(0.014)	(0.36)	(0.26)	(0.006)	
Chicago	3.42	1.35	0.069	3.37	1.19	0.153	Upper Midwest
	(0.30)	(0.28)	(0.007)	(0.26)	(0.26)	(0.015)	
Cleveland	3.55	1.37	0.078	3.22	1.21	0.187	Mideast
	(0.45)	(0.28)	(0.009)	(0.45)	(0.26)	(0.016)	
Dallas	3.10	1.46	0.179	3.15	1.30	0.139	Southwest
	(0.56)	(0.28)	(0.028)	(0.54)	(0.26)	(0.015)	
Detroit	2.83	1.35	0.113	2.97	1.19	0.150	Mideast
	(0.29)	(0.28)	(0.012)	(0.26)	(0.26)	(0.014)	
Hartford	4.02	1.46	0.143	4.16	1.30	0.103	Northeast
	(0.42)	(0.28)	(0.011)	(0.47)	(0.26)	(0.007)	
Kansas City	3.65	1.37	0.096	3.44	1.21	0.176	Central
	(0.57)	(0.28)	(0.009)	(0.56)	(0.26)	(0.021)	
Milwaukee	3.40	1.35	0.036	3.00	1.19	0.142	Upper Midwest
	(0.47)	(0.28)	(0.003)	(0.44)	(0.26)	(0.017)	
Minneapolis	3.79	1.34	0.049	3.48	1.18	0.131	Upper Midwest
	(0.29)	(0.28)	(0.008)	(0.27)	(0.26)	(0.015)	
New Orleans	4.21	1.53	0.160	4.38	1.37	0.125	Southeast
	(0.61)	(0.29)	(0.017)	(0.67)	(0.27)	(0.018)	
Oklahoma City	3.58	1.42	0.132	3.51	1.26	0.133	Central
	(0.48)	(0.28)	(0.020)	(0.46)	(0.26)	(0.024)	
Omaha	3.16	1.36	0.070	2.99	1.20	0.123	Central
	(0.48)	(0.28)	(0.008)	(0.45)	(0.26)	(0.011)	
Philadelphia	3.90	1.46	0.155	3.85	1.30	0.134	Northeast
	(0.54)	(0.28)	(0.013)	(0.53)	(0.26)	(0.015)	
Phoenix	2.69	1.41	0.122	2.70	1.26	0.167	Arizona
	(0.29)	(0.29)	(0.015)	(0.25)	(0.27)	(0.014)	
Saint Louis	3.76	1.37	0.060	3.47	1.21	0.180	Central
	(0.43)	(0.28)	(0.004)	(0.42)	(0.26)	(0.013)	

Seattle	3.82	1.37	0.101	3.41	1.21	0.205	Pacific Northwest
	(0.24)	(0.29)	(0.008)	(0.22)	(0.26)	(0.013)	
Washington DC	3.92	1.45	0.139	3.96	1.29	0.143	Northeast
	(0.51)	(0.28)	(0.010)	(0.56)	(0.26)	(0.012)	
Total U.S.	3.56	1.41	0.110	3.47	1.25	0.148	N/A
	(0.59)	(0.29)	(0.043)	(0.61)	(0.27)	(0.030)	

Note: Standard deviations are reported in the parentheses.

Table A2: Average Retail Prices, Farm Prices, and Expenditure Shares of Skim Milk and Soda for All Cities

	Skim Milk			Soda			
	Retail Price ($/gal)	Farm Price ($/gal)	Expenditure Share	Retail Price ($/gal)	Farm Price ($/gal)	Expenditure Share	Marketing Order
Atlanta	3.76	1.09	0.167	3.10	N/A	0.525	Southeast
	(0.46)	(0.25)	(0.023)	(0.40)		(0.030)	
Boston	3.79	1.06	0.262	2.87	N/A	0.477	Northeast
	(0.36)	(0.24)	(0.023)	(0.40)		(0.027)	
Chicago	3.57	0.93	0.154	2.72	N/A	0.624	Upper Midwest
	(0.31)	(0.24)	(0.015)	(0.28)		(0.034)	
Cleveland	3.35	0.95	0.179	2.79	N/A	0.556	Mideast
	(0.47)	(0.24)	(0.025)	(0.39)		(0.037)	
Dallas	3.33	1.04	0.083	2.83	N/A	0.598	Southwest
	(0.51)	(0.24)	(0.008)	(0.36)		(0.039)	
Detroit	2.99	0.93	0.151	2.75	N/A	0.585	Mideast
	(0.27)	(0.24)	(0.015)	(0.28)		(0.034)	
Hartford	4.39	1.05	0.247	2.96	N/A	0.508	Northeast
	(0.48)	(0.24)	(0.015)	(0.41)		(0.028)	
Kansas City	3.28	0.96	0.163	3.02	N/A	0.564	Central
	(0.59)	(0.24)	(0.019)	(0.31)		(0.041)	
Milwaukee	2.85	0.93	0.217	3.06	N/A	0.605	Upper Midwest
	(0.35)	(0.24)	(0.026)	(0.32)		(0.032)	
Minneapolis	3.45	0.92	0.266	2.90	N/A	0.555	Upper Midwest
	(0.27)	(0.24)	(0.023)	(0.33)		(0.037)	
New Orleans	4.38	1.11	0.119	2.99	N/A	0.596	Southeast
	(0.64)	(0.24)	(0.012)	(0.47)		(0.029)	
Oklahoma City	3.56	1.01	0.081	3.10	N/A	0.653	Central
	(0.54)	(0.24)	(0.010)	(0.32)		(0.046)	
Omaha	2.82	0.94	0.206	3.05	N/A	0.601	Central
	(0.41)	(0.24)	(0.027)	(0.40)		(0.035)	
Philadelphia	3.92	1.04	0.195	2.74	N/A	0.516	Northeast
	(0.53)	(0.24)	(0.021)	(0.38)		(0.033)	
Phoenix	2.88	1.00	0.140	2.84	N/A	0.571	Arizona
	(0.25)	(0.24)	(0.012)	(0.31)		(0.030)	
Saint Louis	3.41	0.96	0.161	2.78	N/A	0.599	Central
	(0.47)	(0.24)	(0.015)	(0.32)		(0.029)	
Seattle	3.57	0.95	0.183	3.46	N/A	0.511	Pacific Northwest
	(0.21)	(0.24)	(0.013)	(0.48)		(0.028)	

Washington DC	4.14	1.04	0.184	3.03	N/A	0.535	Northeast
	(0.57)	(0.24)	(0.0179)	(0.36)		(0.035)	
Total U.S.	3.53	1.00	0.175	2.94	N/A	0.566	N/A
	(0.65)	(0.25)	(0.055)	(0.40)		(0.056)	

Note: Standard deviations are reported in the parentheses.

Table A3: Model Specification of Milk Products in Each City

	Whole Milk		Reduced Fat Milk		Skim Milk	
	Model	Lag Length	Model	Lag Length	Model	Lag Length
Atlanta	ECM	1	ECM	1	ECM	1
Boston	Dist. Lag	1	Dist. Lag	1	Dist. Lag	1
Chicago	ECM	1	ECM	0	ECM	0
Cleveland	ECM	1	ECM	2	ECM	1
Dallas	ECM	1	ECM	1	ECM	0
Detroit	ECM	1	ECM	1	ECM	1
Hartford	Dist. Lag	1	ECM	1	ECM	1
Kansas City	Dist. Lag	1	Dist. Lag	1	ECM	1
Milwaukee	ECM	1	Dist. Lag	1	ECM	0
Minneapolis	Dist. Lag	0	ECM	0	ECM	0
New Orleans	Dist. Lag	2	Dist. Lag	2	Dist. Lag	1
Oklahoma City	Dist. Lag	1	ECM	1	ECM	0
Omaha	ECM	1	ECM	3	ECM	0
Philadelphia	Dist. Lag	1	Dist. Lag	2	ECM	1
Phoenix	ECM	4	ECM	4	ECM	4
Saint Louis	Dist. Lag	1	ECM	1	ECM	1
Seattle	ECM	2	ECM	0	ECM	0
Washington DC	Dist. Lag	3	Dist. Lag	3	ECM	3

Table A4: Summary of Parameter Estimates for Price Transmission Model

	Sum of Coefficients on Changes in Farm Prices					
	Whole Milk		Reduced Fat Milk		Skim Milk	
	$\sum_{r=0}^{k}\beta_{1r}$	$\sum_{r=0}^{k}\beta_{2r}$	$\sum_{r=0}^{k}\beta_{1r}$	$\sum_{r=0}^{k}\beta_{2r}$	$\sum_{r=0}^{k}\beta_{1r}$	$\sum_{r=0}^{k}\beta_{2r}$
Atlanta	0.852**	0.114	1.003**	-0.019	0.837**	0.154
	(0.218)	(0.261)	(0.275)	(0.275)	(0.218)	(0.211)
Boston	0.536**	-0.117	0.631**	-0.172	0.532**	-0.077
	(0.116)	(0.185)	(0.126)	(0.188)	(0.116)	(0.146)
Chicago	0.560**	0.341	0.258	0.542	0.247	0.603*
	(0.201)	(0.332)	(0.164)	(0.283)	(0.135)	(0.255)
Cleveland	0.242	0.692	0.426	1.001*	0.280	0.490
	(0.263)	(0.382)	(0.319)	(0.407)	(0.224)	(0.278)
Dallas	0.540**	0.320	0.594**	0.267	0.368*	0.325
	(0.189)	(0.339)	(0.178)	(0.338)	(0.157)	(0.281)
Detroit	0.396	0.510	0.499*	0.395	0.414*	0.403
	(0.218)	(0.353)	(0.215)	(0.367)	(0.205)	(0.267)
Hartford	0.523**	0.247	0.528**	0.280	0.455**	0.286
	(0.093)	(0.196)	(0.087)	(0.190)	(0.105)	(0.151)
Kansas City	0.694**	0.151	0.827**	0.118	0.821**	0.137
	(0.087)	(0.106)	(0.109)	(0.136)	(0.096)	(0.100)
Milwaukee	0.567**	0.165	0.599**	0.319	0.423**	0.304
	(0.165)	(0.279)	(0.143)	(0.278)	(0.109)	(0.185)
Minneapolis	0.359	0.316	0.317	0.404	0.296	0.462*
	(0.251)	(0.377)	(0.233)	(0.308)	(0.174)	(0.227)
New Orleans	0.831**	0.124	0.839**	0.106	0.437*	0.599**
	(0.199)	(0.236)	(0.187)	(0.234)	(0.173)	(0.189)
Oklahoma City	0.515*	0.350	0.651**	0.269	0.453**	0.419
	(0.233)	(0.444)	(0.229)	(0.464)	(0.144)	(0.286)
Omaha	1.107**	0.127	1.792**	0.185	0.812**	0.223
	(0.169)	(0.281)	(0.293)	(0.297)	(0.118)	(0.175)
Philadelphia	0.639**	0.184*	0.838**	0.014	0.603**	0.157
	(0.067)	(0.082)	(0.114)	(0.128)	(0.079)	(0.088)
Phoenix	0.286	0.789*	1.186**	0.096	1.300**	0.159
	(0.355)	(0.365)	(0.392)	(0.324)	(0.430)	(0.298)
Saint Louis	0.579**	0.068	0.787**	0.162	0.656**	0.230
	(0.108)	(0.214)	(0.186)	(0.318)	(0.164)	(0.225)
Seattle	0.380	0.773*	-0.034	0.700**	0.086	0.508**
	(0.263)	(0.385)	(0.132)	(0.222)	(0.094)	(0.178)
Washington DC	0.701**	0.010	0.749**	0.026	0.579**	0.062
	(0.127)	(0.155)	(0.131)	(0.134)	(0.131)	(0.159)

Note: Robust standard errors are reported in the parentheses. $\sum_{r=0}^{k}\beta_{1r}$ is the cumulative price response to a decrease in farm price for product i over k periods and $\sum_{r=0}^{k}\beta_{2r}$ is the difference in the cumulative price responses between an increase in farm price and a decrease over k periods.

**significant at 0.01 significance level

*significant at 0.05 significance level

Table A5: Parameter Estimates of the K-AIDS

	Dependent Variables (Expenditure Shares)			
Independent Variables	Whole Milk	Reduced Fat Milk	Skim Milk	Soda
Price:				
Whole Milk	-0.0030**	0.0130**	0.0065**	-0.0164**
	(0.0011)	(0.0020)	(0.0016)	(0.0039)
Reduced Fat Milk	0.0130**	0.0288**	0.0170**	-0.0587**
	(0.0020)	(0.0031)	(0.0022)	(0.0054)
Skim Milk	0.0065**	0.0170**	0.0078**	-0.0312**
	(0.0016)	(0.0022)	(0.0019)	(0.0036)
Soda	-0.0164**	-0.0587**	-0.0312**	0.1064**
	(0.0039)	(0.0054)	(0.0036)	(0.0118)
Squared Price:				
Whole Milk	-0.0002**	-0.0007**	-0.0014**	0.0023**
	(0.0001)	(0.0002)	(0.0003)	(0.0006)
Reduced Fat Milk	0.0134**	0.0028**	0.0046**	-0.0207**
	(0.0018)	(0.0008)	(0.0008)	(0.0027)
Skim Milk	0.0005*	0.0001	0.0035**	-0.0040**
	(0.0002)	(0.0002)	(0.0006)	(0.0008)
Soda	0.0549**	0.0575**	0.0744**	-0.1868**
	(0.0063)	(0.0064)	(0.0073)	(0.0141)
Expenditure	0.0004	-0.0149**	-0.0298**	0.0442**
	(0.0010)	(0.0011)	(0.0015)	(0.0022)
% Black Population	0.2299	-0.3562*	-0.3542*	0.4805
	(0.2066)	(0.1398)	(0.1662)	(0.0806)
% of Hispanic Population	0.2424**	-0.2677**	0.1261**	-0.1007
	(0.0855)	(0.0503)	(0.0356)	(0.0368)
% of Asian Population	0.6398**	-0.3371**	-0.0272**	-0.2755
	(0.1043)	(0.0443)	(0.0354)	(0.0446)
% of Households with Income < $25,000	-2.1409**	2.3447**	-1.5695**	1.3657
	(0.4214)	(0.1739)	(0.2477)	(0.1873)
% of Households with Income > $75,000	-0.3148**	0.4878**	-0.4086**	0.2356
	(0.1033)	(0.0511)	(0.0659)	(0.0452)
City Dummy Variables:				
Atlanta	-5.4285**	3.8330**	0.5975	0.9981**
	(0.8099)	(0.3433)	(0.3608)	(0.3460)
Boston	-10.7651**	2.4160**	5.4617**	2.8874**
	(1.4742)	(0.5453)	(0.5516)	(0.5696)
Chicago	-2.7733**	-3.1059**	-0.2300	0.5625
	(1.0621)	(0.5752)	(0.2744)	(0.4748)
Cleveland	2.0304**	-1.5850**	1.2949**	-1.7403**
	(0.6068)	(0.2841)	(0.2814)	(0.2627)
Dallas	-1.9478	6.1983**	-7.4269**	3.1764**

	(1.0342)	(0.4623)	(0.8203)	(0.5110)
Detroit	-3.5220**	1.9210**	1.0877**	0.5133*
	(0.4948)	(0.1933)	(0.2805)	(0.2028)
Hartford	-11.2740**	2.6093**	5.6149**	3.0498**
	(1.4969)	(0.5387)	(0.5561)	(0.5833)
Kansas City	-0.5361	0.0509	1.0351**	-0.5500**
	(0.2783)	(0.1276)	(0.1734)	(0.1110)
Milwaukee	13.5747**	-9.8293**	4.3896**	-8.1349**
	(2.4967)	(1.0588)	(0.8620)	(1.1957)
Minneapolis	13.7668**	-10.4795**	4.1828**	-7.4701**
	(2.5612)	(1.1123)	(0.8164)	(1.2130)
New Orleans	2.2248**	4.5008**	-8.7675**	2.0419**
	(0.7766)	(0.4604)	(0.7302)	(0.4039)
Oklahoma City	16.6966**	-1.6889*	-16.6174**	1.6097*
	(2.4995)	(0.8293)	(1.8246)	(0.7375)
Omaha	-3.4116**	-1.0364*	3.0357**	1.4122**
	(0.6824)	(0.4310)	(0.2983)	(0.2014)
Philadelphia	-9.0218**	3.6524**	3.3653**	2.0041**
	(1.1856)	(0.4374)	(0.4386)	(0.4887)
Phoenix	-2.7301**	1.7111**	-0.5107	1.5297**
	(0.5656)	(0.2682)	(0.3601)	(0.2298)
Saint Louis	5.3686**	-3.7358**	1.6142**	-3.2470**
	(1.1448)	(0.5268)	(0.4121)	(0.5256)
Seattle	0.8821	-0.0972	0.0639	-0.8488**
	(0.4704)	(0.2741)	(0.2330)	(0.2234)
Washington DC	-8.6805**	4.6651**	1.8093**	2.2061**
	(1.1848)	(0.4633)	(0.4304)	(0.5002)
Intercept	-0.0488**	0.0310*	-0.0027	1.0205**
	(0.0102)	(0.0122)	(0.0084)	(0.0224)
R-sq	0.923	0.848	0.914	N/A

Note: Robust standard errors are shown in the parentheses. The unit for expenditure is $10 per capita. There are 2,376 monthly observations.
**significant at 0.01 significance level
*significant at 0.05 significance level

Table A6: Compensated and Expenditure Elasticities for All Products

	Price				
Quantity	Whole Milk	Reduced Fat Milk	Skim Milk	Soda	Expenditure
Whole Milk	-0.922**	0.291**	0.247**	0.384**	1.005**
	(0.012)	(0.015)	(0.011)	(0.008)	(0.011)
Reduced Fat Milk	0.188**	-0.646**	0.283**	0.175**	0.896**
	(0.022)	(0.022)	(0.014)	(0.010)	(0.026)
Skim Milk	0.125**	0.260**	-0.793**	0.407**	0.810**
	(0.019)	(0.015)	(0.013)	(0.006)	(0.039)
Soda	0.091*	0.041*	0.128**	-0.259**	1.079**
	(0.043)	(0.038)	(0.024)	(0.022)	(0.004)

Note: Robust standard errors are reported in the parentheses. The average elasticities across all observations are reported.
**significant at 0.01 significance level
*significant at 0.05 significance level